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The WELDING Journal

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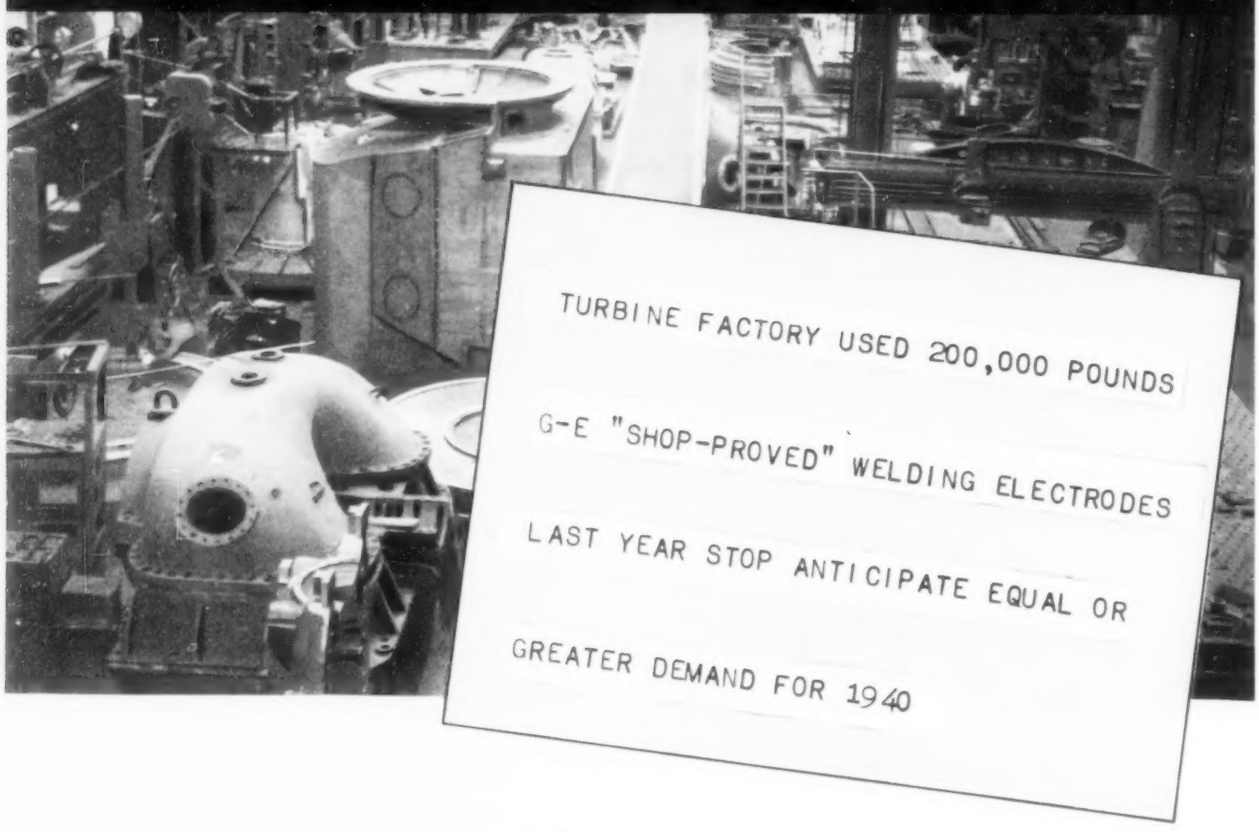
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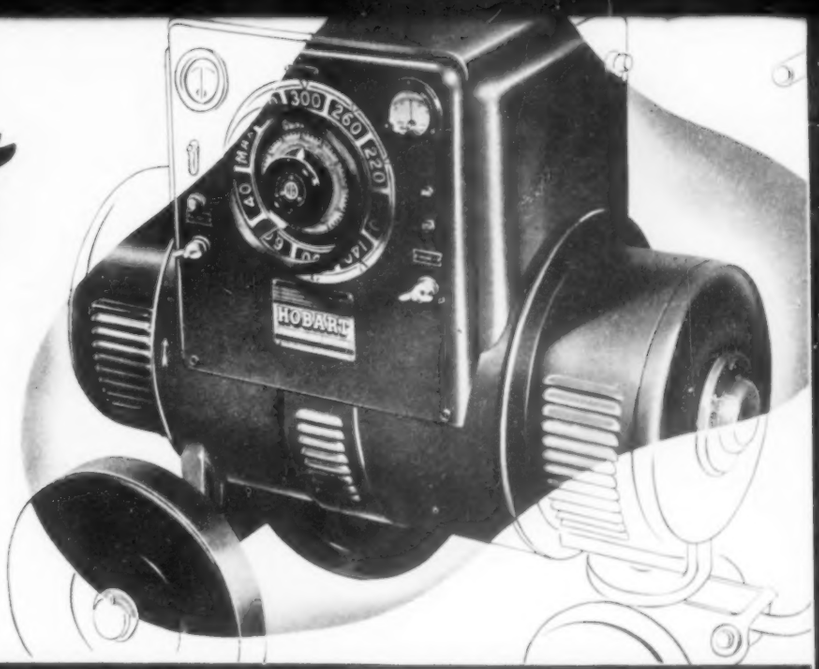

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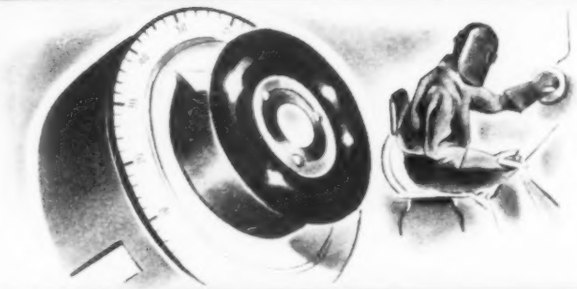

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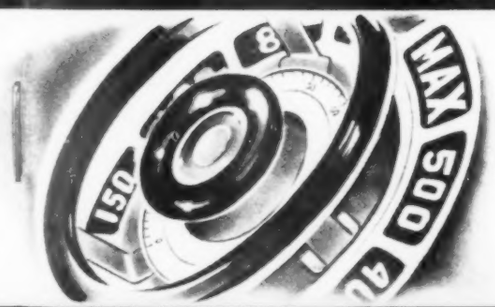

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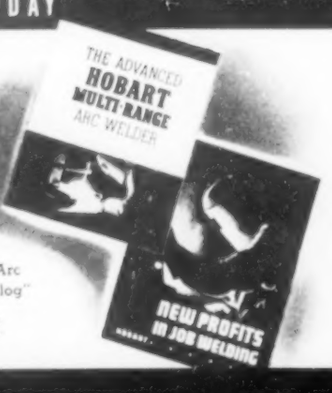

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A 1,500,000-gallon elevated water tank of radial-cone bottom design built for the Indianapolis Water Company at Indianapolis, Indiana. *Photo courtesy Chicago Bridge & Iron Company.*

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Subscription $5.00 per year in United States and possessions; $5.50 in Canada and Mexico; Foreign Countries $7.00. Single copies, non-members $.75; Special issues October and December $1.00; members 50 cents.

Entered as second-class matter January 15, 1932, at the post-office at Easton, Pa., under the Act of March 3, 1879.

PUBLICATION OFFICE
20th & Northampton Streets, Easton, Pa.

EDITORIAL AND GENERAL OFFICES
33 West 39th St., New York, N. Y.

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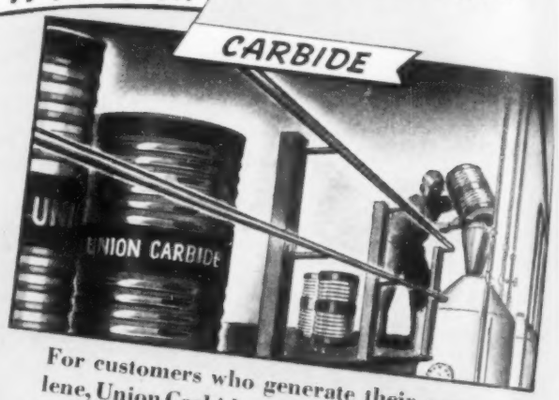

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VOLUME 19, No. 1 JANUARY 1940

PLATE EDGE PREPARATION for Welding*

By H. E. ROCKEFELLER†

EVER since the inception of fusion welding for joining plate oxyacetylene cutting has been employed for preparing the plate edges for welding. Practically everyone engaged in plate fabrication has made use of the cutting process in one form or another for the preparation of the plate edges. The growth of application for the oxyacetylene cutting process has been brought about largely through the low cost of the required equipment, the flexibility of its application, and the speed with which the desired results may be secured. There is little question but that many of the structures which we see today which have been fabricated by fusion welding would not have been economically practicable had oxyacetylene cutting not been available for the preparation and shaping of the edges to be joined.

The general subject of oxyacetylene plate edge preparation is a broad one. It includes all cutting operations which may be required for the preparation of the plate, whether the desired edge shape is to be square, beveled, grooved or some combination of these forms. The general subject includes the manual application of the cutting blowpipe such as for nozzle openings, etc., and the mechanical shape-cutting of irregular contours. The present discussion, however, will be limited, in general, to the subject of machine flame cuts for the preparation of rectangular plates.

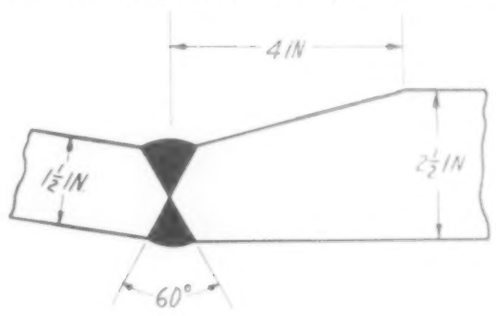
Until recently oxyacetylene cutting for the preparation of plate edges has been confined to the use of a single cutting nozzle and individual cuts. An interesting example of the application of this method which required four passes of the cutting nozzle to develop the desired edge contour was in the preparation of the circumferential segments for the reducing bends in the 18-ft. diameter Penstocks for the Grand Coulee Dam. The cross-sectional sketch of the plate edge contour for this job in Fig. 1 shows the four separate cuts which had to be made. The first three of these cuts were required to prepare a type of joint form which is classified as double vee and nose. A fourth cut was used to taper the $2^1/_2$ in. thick material to a $1^1/_2$ in. thickness so that a satisfactory joining to an abutting $1^1/_2$ in. thick plate could be accomplished. The equipment used to produce the desired edge contour is illustrated in Fig. 2. It will be noted that a curved templet is being used to guide the cutting machine along the line of curvature of the Penstock section.

The beveling of flanged and dished heads provides another interesting example of the single nozzle method of edge preparation. It will be noted that in all of these first few examples standard cutting machine equipment is in general being employed. In Fig. 3 we see the outside bevel of the dished head being cut. The blowpipe is held in its normal mounting on the standard cutting machine and is preparing the desired bevel through the use of a bevel cutting adapter. In Fig. 4 an extension arm is used for positioning the blowpipe to produce the inside bevel. Notice that in this application a mounting plate is required to provide a base for the operation of the cutting machine.

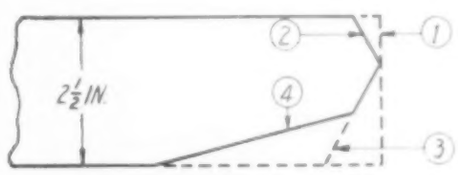
In Fig. 5 is illustrated a method which may be used to avoid the need for a machine mounting plate. By the use of a flexible radius arm attachment the cutting machine may be operated directly on the head.

NEWER DEVELOPMENTS

Although the methods which have been shown produce satisfactory edge preparation for joining by fusion weld



DETAIL "B" - CROSS-SECTION THROUGH DOUBLE VEE WELD BETWEEN LAST TWO BEND SEGMENTS



THE NUMBERS INDICATE SEQUENCE OF CUTS ON 2½ IN THICK PLATE

Fig. 1—Design of Edge Contour of the Circumferential Segments for the Reducing Bends in the 18-Ft. Diameter Penstocks for Grand Coulee Dam

* Presented before the 20th Annual Meeting of the AMERICAN WELDING SOCIETY, October 22 to 29, Chicago.

† Manager, Process Development, The Linde Air Products Company, New York.

Fig. 2—Cutting the Edge Contour Shown in Fig. 1

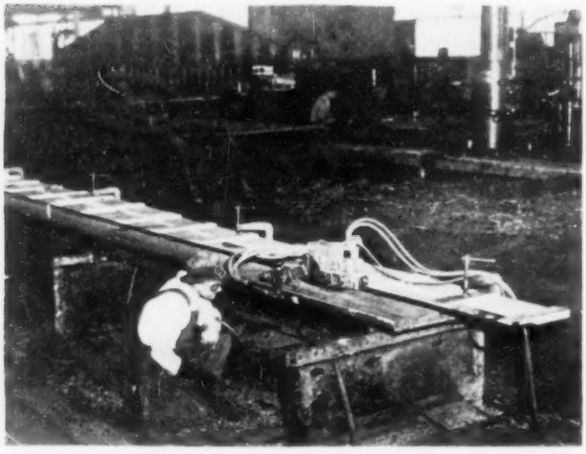


Fig. 3—Cutting the Outside Bevel on a Dished Head

ing, more recent developments have indicated possibilities of broadening the scope of oxyacetylene plate edge preparation by increasing the speed and reducing the cost of cutting, while still providing improved accuracy both in the contour and straightness of the prepared edges. These new developments include a process which indicates the possibility of producing grooved preparations in place of beveled edges.

For some time it has been generally recognized that increased speed of cutting can be obtained by the use of what has been termed a leading lag. With the cutting blowpipe held in a vertical position with respect to the work and being moved forward at a reasonable speed, the cut does not extend through the work directly in line with the cutting blowpipe but lags behind, particularly at the bottom, by a varying amount depending upon a number of conditions. By tilting the blowpipe nozzle forward in the direction of the cut, a leading lag is secured. The increased speed that is thus obtained, however, results in a surface which is rough and unsatisfactory for plate edge preparation. If a second nozzle is employed, placed in proper relationship to the leading nozzle, full advantage of the speed of leading lag cutting can be obtained and, at the same time, a quality of cut surface will result which is equivalent to that secured with a single nozzle when operated at considerably lower speeds. Figure 6 illustrates the comparative results which are obtained in the cutting of $^1/_2$-in. plate with a single nozzle and with the method which has just been described and which has been called the cut-and-trim method.

In the case of the cut and trim method, the cutting speed was 36 in. per min., while the single nozzle method progressed at the rate of 18 in. a minute. The cutting oxygen consumption for the cut and trim method was 1.28 cu. ft. per ft. as against 1.12 cu. ft. per ft. for the single nozzle method. Thus, the cut and trim method provided an increase in speed of 100 per cent while only consuming about 10 per cent more cutting oxygen. The surface quality obtained with the cut and trim method, furthermore, was superior to that with the single nozzle method.

There are times when the plate edge preparation requires a single bevel and nose, a double bevel, or a double bevel with nose. It will be recalled that the Grand Coulee Penstock sections required a double bevel with nose while the dished heads required a double bevel, and also that each of these cuts required an individual pass of the cutting machine. Recent developments have resulted in procedures and equipment wherein these preparations may be produced by the simultaneous operation of two or more cutting nozzles so that the desired contour is made with a single pass of the cutting equipment. Figure 7 shows the representative contours which have been produced by the simultaneous method of preparation. The success of this method depends upon the positioning of the different nozzles in such a manner as to provide the proper relationship between the succeeding reaction zones. It has been found that if the nozzles are too close together there will be a fouling of one jet by another.

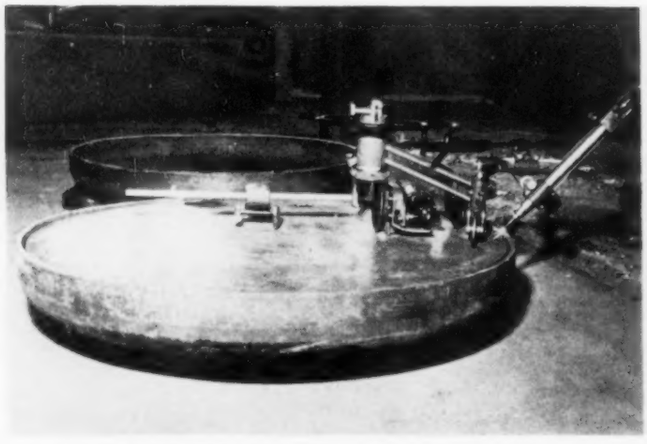


Fig. 4—The Inside Bevel for a Dished Head Is Cut by the Use of an Extension Arm for Positioning the Blowpipe

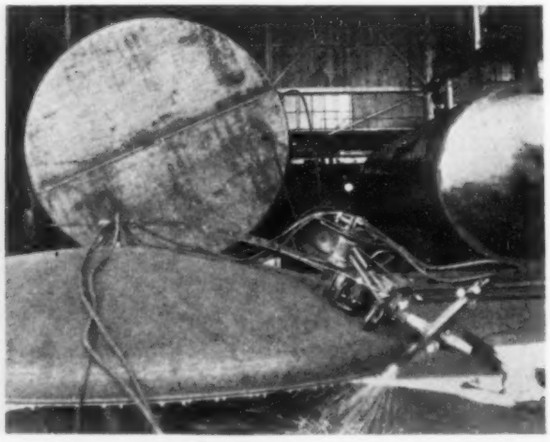


Fig. 5—The Mounting Plate Shown in Figs. 3 and 4 May Be Avoided Through the Use of a Flexible Radius Arm Attachment to the Cutting Machine

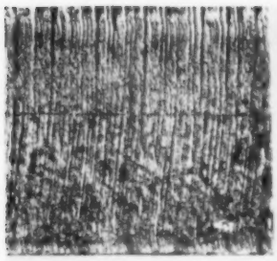


Fig. 6 (Top)—Edge of 1-In. Plate Square Cut by the Single Nozzle Method. (Bottom) Edge of 1-In. Plate Square Cut by the Cut and Trim Nozzle Method

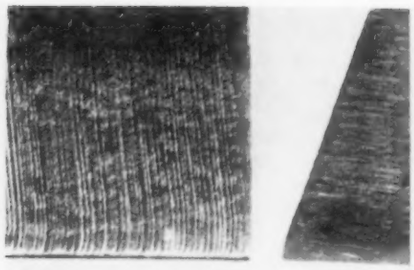


Fig. 7A (Top)—Edge of 1-In. Plate Plain Beveled by Single Nozzle Method. (Bottom) Edge of 1-In. Plate Square Cut and Beveled to 30 Deg. and 1/8 In. Wide Nose

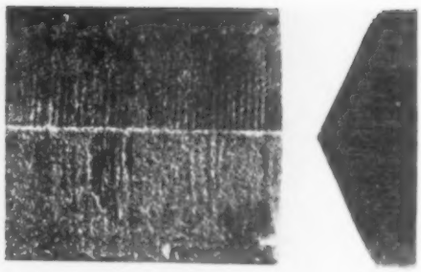


Fig. 7B (Top)—Edge of 1-In. Plate Double Vee Beveled to 30 Deg. (Bottom) Edge of 1-In. Plate Square Cut and Double Vee Beveled to 30 Deg. and 1/8 In. Wide Nose

On the other hand, if the nozzles are too far apart, a proper heat balance between the reaction zones is not maintained. To effect an economical result and a smooth contour, it is necessary, therefore, that care be taken to position the nozzles properly with respect to one another.

PLATE RIDING DEVICE

One of the problems which arose in the application of oxyacetylene cutting for plate edge preparation, particularly in the case of long cuts, was the need for maintaining an exact interval of space between the tip of the cutting nozzle and the surface of the plate. A wavy condition in the plate or the sagging of the work between supports made this adjustment rather difficult until the development of a device for floating the blowpipes so that the distance from the nozzle to the work would automatically be maintained constant. In the case of machine tool planing, the waves normally encountered in long plates are eliminated or reduced to within a practical limit by the use of pressure applied along the edge of the plate being prepared, usually by means of hydraulic jacks. The development of a blowpipe floating mechanism, or plate-riding device as it has been termed, however, eliminated the necessity for flattening the plate by mechanical means, thereby simplifying both set-up and investment cost.

One design of riding device developed for use with standard straight line cutting machines is illustrated in Fig. 8. The horizontal arrangement of the framing on this device permits the mounting and positioning of all blowpipes required for any type of bevel contour. The maintenance of the desired angles as the blowpipes are raised and lowered with respect to the cutting machine itself is accomplished by a system of parallel linkage. The two wheels of the plate-riding device are so positioned that contact with the plate is maintained for the entire length of the cutting operation. One wheel has been placed on each side of the blowpipe so that the proper distance between cutting nozzle and plate will be maintained at the start and finish of the cut as well.

Figure 9 shows a plate edge preparation set-up involving the simultaneous cut and single bevel preparation on several thousand 1/2-in. plates. These plates were to be 6 ft. x 13 ft. and it was found that it was necessary to remove from 1 to 2 in. of excess metal from the 6-ft. sides. In the original plans for accomplishing this it was contemplated that all four sides of these plates would be planed. The specified contour was a 22 1/2-deg. bevel angle with a 3/16 in. wide nose.

In order to remove the excess metal from the 6-ft.

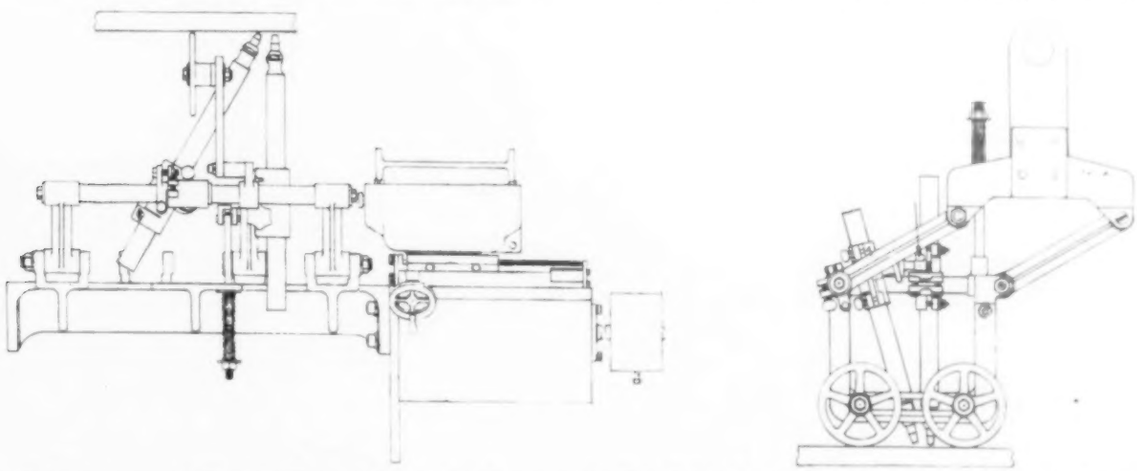


Fig. 8—Arrangement of Blowpipe Floating Mechanism, Known as the Plate Riding Device, as Set Up for Square Cutting and Beveling

sides more economically, it was decided to prepare the ends by flame-cutting and the 13-ft. sides by planing.

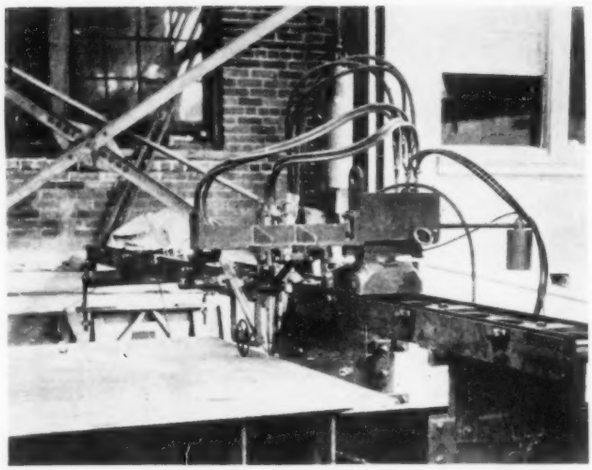
A description of the method of handling these plates is important to a consideration of the entire job. The plates were handled by an air jack type of monorail hoist. They were lifted from the flat car adjacent to the cutting table and placed in position for cutting one edge. After this had been done they were raised, turned and placed in position for cutting the other edge. They were then lifted from the table and transported a distance of 25 ft. and stacked. The cutting machine operator performed these tasks without any assistance. He also removed any adhering slag from the cut edge. The average over-all time required for handling each plate and preparing two 6-ft. long edges was 20 min. Eight minutes of this time were consumed by the actual cutting. Approximately 30 cu. ft. of oxygen and 6 cu. ft. of acetylene were required to cut the two edges of each plate.

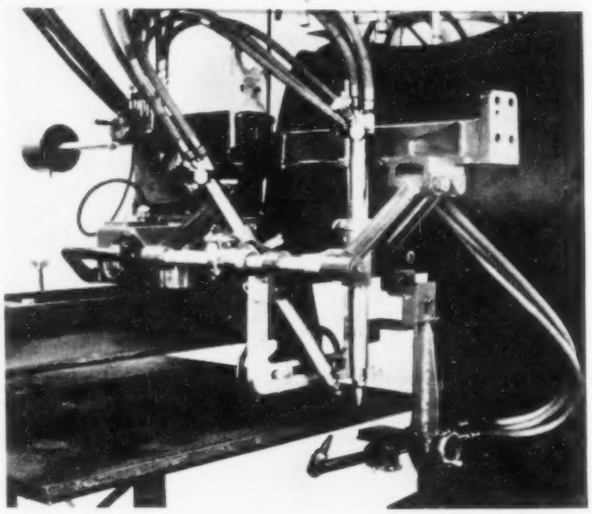
Another application of the simultaneous method of plate edge preparation involving a double vee and nose contour is illustrated in Fig. 10. This application was made in a shipyard in the fabrication of oil tankers. The design called for the butt-welding of the plate ends to make each strake a continuous steel plate from bow to stern. Although the plate sides were to be riveted, butt-welding of plate ends eliminated the need of passing rivets through more than two-plate thicknesses at the plate corners, and also eliminated the expensive machining required to scarf these plate corners. The sides of the plates which were to be riveted were to be prepared with a square edge contour. The welding edge contour specified for the plate ends was a 30-deg. double vee bevel with a square nose of $^1/_8$ in. In order to meet this specification with a single pass of the cutting equipment, three flame-cutting blowpipes operating simultaneously were required.

The plates were handled with a shop bridge-type crane. They were lifted from a stack adjacent to the cutting area and placed on supporting horses. The cutting unit, consisting of the track, cutting machine and blowpipe assembly including the riding device, was so designed that it could be clamped as a unit for portable use. The unit was transported by the shop crane and positioned on the plate to layout marks. Telescoping index rods fastened to the track simplified this positioning. After one end had been cut, the entire unit was picked up by the crane and moved to the other end of the plate. When both ends had been cut, an operator with a straight line portable cutting machine made the square cuts required on the sides of the plate.

The average over-all time required to handle the bevel-cutting unit and prepare a welding edge on two sides of a 9-ft. plate, $^7/_8$ in. thick, was 35 min. About 7 min. of this time, on the average, were consumed while waiting for the crane. The oxygen consumption per plate averaged 108 cu. ft. and the acetylene consumption 20 cu. ft.

Some other examples for the application of oxyacetylene cutting will be interesting and instructive. Unusual opportunities for economy and time saving in the preparation of heavy plates for boiler drums and pressure vessels are offered in those cases where the plates must be rolled or pressed to curvature prior to edge preparation. In most instances considerable excess metal must be provided prior to forming to insure sufficient metal for the proper curvature of the finished edge. By the use of the simultaneous cut and bevel principle, the excess metal may be removed and a double vee and nose preparation developed, all in a single operation. While the set-up shown in Fig. 11 illustrates the double bevel and nose preparation on flat plate, the same equipment has been employed for curved plate cutting, it being only





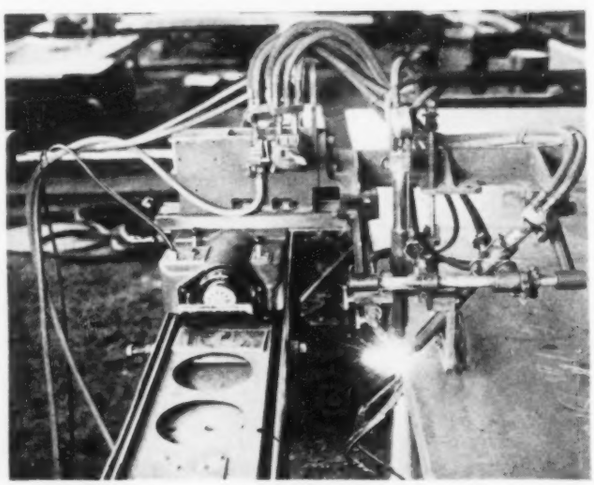


Fig. 9 (Top)—Equipment for Simultaneous Square Cut and Bevel for Edge Preparation

Fig. 10 (Center)—Equipment for Simultaneous Square Cut and Bevel for Edge Preparation, Including Attachment for Under-Beveling

Fig. 11 (Bottom)—Equipment in Action Simultaneously Preparing Double Vee Bevel and Straight Nose

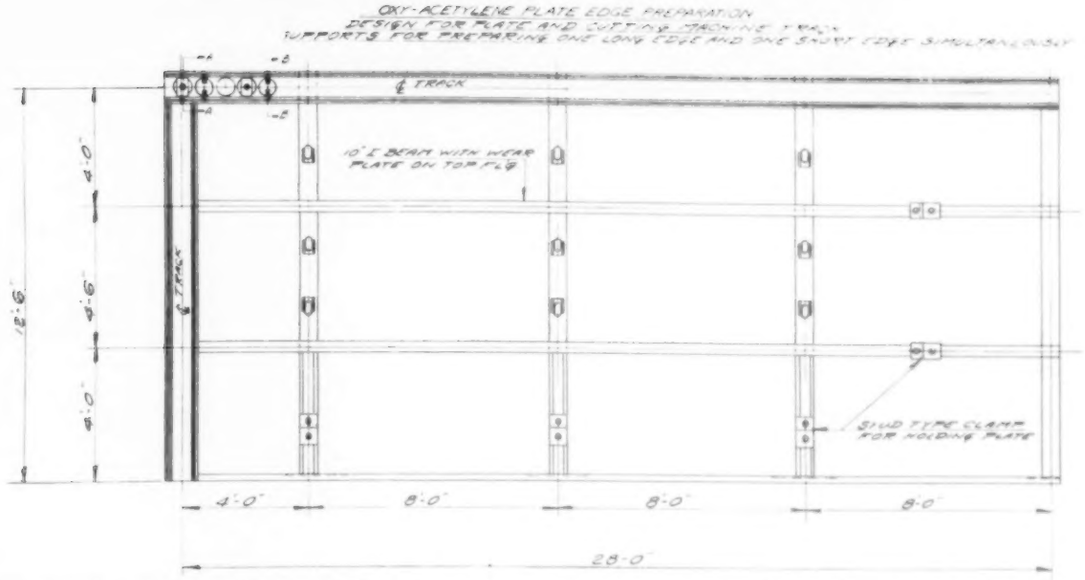

OXY-ACETYLENE PLATE EDGE PREPARATION
DESIGN FOR PLATE AND CUTTING MACHINE TRACK SUPPORTS FOR PREPARING ONE LONG EDGE AND ONE SHORT EDGE SIMULTANEOUSLY
℄ TRACK
10" I BEAM WITH WEAR PLATE ON TOP FLG
℄ TRACK
STUD TYPE CLAMP FOR HOLDING PLATE
4'-0"
8'-0"
8'-0"
8'-0"
28'-0"

Fig. 12—Design for Plate and Cutting Machine Track Support for Preparing One Long Edge and One Short Edge Simultaneously

necessary to position the plate properly for this operation.

Figure 12 illustrates an L-shaped set-up which appears to have considerable merit for the edge preparation of square plates. By the use of this set-up, plate layout can be eliminated. Two edges of the plate are cut simultaneously as close to the rolled or sheared edge as can be accomplished. With two edges thus prepared, the plate is swung around 180 deg. and positioned against stops which automatically determine the finished length and width of the completed plate. A number of variations of this design can be employed including a parallel track assembly for the simultaneous cutting of two parallel edges, variation in widths of plate being provided for by cross-slide adjustment on the cutting machine units.

PLATE GROOVING

The use of a curved groove, commonly referred to as a U- or J-groove depending upon its dimensions, appears to be increasingly replacing the more common vee preparation. The advantages claimed for the curved groove are that it provides a more satisfactory design for deposition of the initial weld bead and, in the case of heavy plate, requires less weld metal for the joint. Where it is necessary in welded joint design to use a square edge on one side of the joint, such as for some nozzle intersections, corner joints, etc., the J-groove offers an improved design for the abutting plate edge.

Recent advances in oxyacetylene nozzle developments indicate that this process may find a broad field of application in grooving as well as beveling for plate edge preparation. Commercial introduction is now being made of a series of specially constructed nozzles by the use of which grooves simulating the one-half U- and J-type grooves can be produced on plate edges. It is also possible with these nozzles to develop a full U-groove in abutting plate edges. A considerable variation in the contour of edge preparation can be secured with a single nozzle by varying the horizontal and vertical angles of the nozzle with respect to the work. The oxygen pressure and speed of the operation are two other variables which effect the contour produced. An indication of the variation in contour which may be obtained with a single nozzle is illustrated in Fig. 13.

In Fig. 14 is shown the application of the grooving method on rectangular plates. The plate is set up on a planer bed in the same manner that it would be for a tool-planing operation. A special nozzle, however, takes the place of the tool, and the complete contour is developed by a single pass of the work by the nozzle. For developing a similar groove on a circular plate the same general principles are employed as illustrated in Fig. 15. In this instance the plate is placed on a turntable and rotated past the nozzle.

There has already been application for oxyacetylene grooving for the development of a full U-groove contour on abutting plate edges but this has, for the most part, been applied as a partial or secondary preparation on joints which have been welded from one side. The operation consists of grooving out the underside of the welded joint in such a manner as to provide a satisfactory preparation for welding the second side of the joint and, thus, to develop a double-welded butt joint.

The operation may, however, be applied as an initial preparation other than plate squaring. In this case the plates are either abutted or spaced apart as shown in Fig. 16. A single weld bead is then deposited to hold the plates in position and to form a bottom shelf for the grooving operation. Because of the ease with which the contour can be controlled, the grooving operation is often carried out by manual manipulation.

In Fig. 17 is illustrated the manual application of U-grooving on the deck plates of a dredge. In this picture the operator is gouging a groove between two plates butted together.

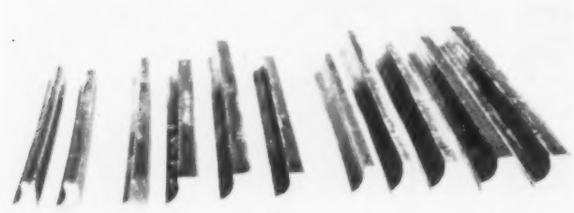
ACCURACY OF OXYACETYLENE CUTTING

For certain applications of plate edge preparation the permitted tolerances in the cross-sectional contour and the straightness of the prepared edge have provided a limiting condition in the present application of the oxyacetylene cutting process. A discussion of the accuracy obtainable in oxyacetylene plate edge preparation may therefore be of assistance in establishing the suitability and the procedures to be followed for specific applications.

The accuracy of oxyacetylene plate edge preparation depends principally upon three factors. One is the me-

chanical accuracy of equipment employed or, in other words, the accuracy with which the cutting nozzle or nozzles may be propelled along the desired line of cut. Another factor is the accuracy with which the cutting jet can be controlled in its removal of metal. The third factor involves the question of plate movement or distortion resulting from the heat absorbed by the plate during the cutting operation.

Cutting machines employed to date for plate edge preparation have been, for the most part, of the Monitor type which operate on tracks. Mechanical accuracy of the nozzle movement on such machines is largely determined by the straightness of the track, since most of the propulsion units, when kept in good repair, will operate with an accuracy of within a few thousandths of an inch. The accuracy of the track is, of course, largely a matter of care in preparation and maintenance.



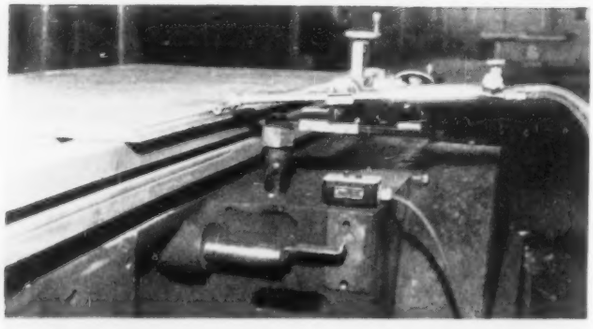


Fig. 13 (Top)—Some of the Variations in Contour Which May Be Obtained with a Single Grooving Nozzle

Fig. 14 (Center)—Method for Securing J-groove Contour on Rectangular Plates

Fig. 15 (Bottom)—Method for Securing J-groove Preparation on Circular Plates

While the general practice of preparing plate edges by portable oxyacetylene cutting machines which can be taken to the work offers definite advantages for certain applications because of the reduced handling of the plate material, there are often considerable delays involved in moving equipment from one edge to the other and in aligning it accurately in reference to the line to be cut. The use of portable equipment, furthermore, often increases the chance for mechanical inaccuracy in cutting, since it is difficult to maintain the track and machine adjustment when it is being continually moved from place to place about the shop. The maximum mechanical accuracy in routine production, therefore, will be obtained when a stationary plate edge installation is employed, wherein the plate is brought to the machine.

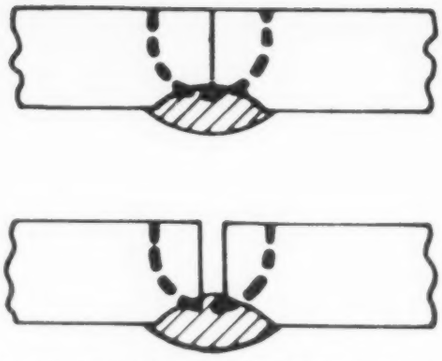


Fig. 16—Plates for Grooved Preparation May Be Either Abutted or Spaced Apart as Shown

To discuss the second factor affecting the accuracy of oxyacetylene cutting, namely, the control of the cutting jet, variations from the desired cross-sectional contour attributable to the oxygen stream are largely a matter of accuracy of drilling of the oxygen bore and the proper maintenance of the cutting nozzle. If the nozzles are properly cared for and so positioned in operation that there will not be slag interference, variation in contour due to the oxygen stream should be maintained within a tolerance of 0.015 in. per inch of plate thickness.

The third factor is one which has attracted considerable attention. Distortion of a plate edge resulting from the heat applied during the cutting operation is probably the most difficult factor to control. As is well known, when heat is applied to a plate edge as it is in flame-cutting, the edge tends to expand and, since the heat is applied progressively, the total force due to expansion increases in magnitude as the cutting operation

Fig. 17—The Manual Application of U-Grooving on the Deck Plates of a Dredge. The Groove Is Being Prepared Between Two Plates Butted Together

progresses. To relieve this force the edge tends to assume a convex or outward bow. When the cut is completed and the edge temperature decreases, the edge metal gradually resumes its full strength and contracts with the decreasing temperature. If, during the heating cycle, restraint has prevented free expansion, the metal will upset and, upon cooling, the edge will assume a concave or inward bow. On plate $^3/_8$ in. in thickness and under, the thermal stresses are sufficiently relieved by surface distortions, that is, by warping or buckling of the plate surfaces, to minimize the edge upsetting effect. Since, on the other hand, the stiffness of the plate increases with thickness, on plates above 1 in. in thickness the amount of distortion resulting from the heat effect is also reduced.

A large number of experiments have indicated that the total maximum deviation from a straight line to be expected on flat plates having a width greater than 3 ft., regardless of length, is about $^1/_{16}$ in. Where the cut length is 10 ft. or less or the thickness less than $^1/_2$ in., the over-all distortion will very seldom exceed $^1/_{32}$ in. For most applications of plate edge preparation involving square edge, bevel or bevel and nose contours, therefore, the accuracy of preparation can easily be maintained within practical limits. For plates which are to be rolled into cylindrical sections subsequent to edge preparation, the small deviations in the straightness of the edge resulting from the use of oxyacetylene cutting can usually be compensated for in the alignment of the sections for welding.

For full U-groove operations of abutting plate edges, no measurable distortion is normally encountered; the limitation in accuracy being one of cross-sectional contour. The cross-sectional contour of U- or J-grooves when prepared by the oxyacetylene method cannot be controlled to the same degree of accuracy as can be accomplished in machine tool planing. However, because of the flexibility and speed of preparation of the oxyacetylene method, acceptable commercial applications have been made and it is evident that further use of this method will be made as its possibilities, as well as its limitations, are more thoroughly appreciated. In a number of commercial applications which have been made by this method to date, no objection has been raised regarding the limitation of accuracy in the cross-sectional contour.

There has been a great amount of data compiled and presented on the resultant effect of cutting on the cut edge of the metal from a metallurgical standpoint. The question still arises, however, in connection with plate edge preparation for fusion welding. For those who are not acquainted with the data which have been developed on this subject, the following summary may be of interest. It has been conclusively proved that such effects as result from cutting on plate edges are due almost entirely to the rapid cooling or metal quench effect on the cut edge. When it is appreciated that during the welding operation the metal in the heat-affected zone is subjected to the same type of metal quench as in cutting, it is readily understandable why no troubles have been encountered as a result of torch cutting on such materials as are satisfactory for welding without any unusual precautions. In other words, if the plate material is satisfactory for welding without any unusual precautions being taken, it is also satisfactory for preparation for welding by oxyacetylene cutting. It is also obvious that the heat-affected zone formed during the cutting operation for plate edge preparation will be entirely eliminated during the welding operation. The American Society of Mechanical Engineers Boiler Code Committee, recognizing these facts in 1935, removed all restrictions in the Boiler Code pertaining to welding on flame-cut surfaces for materials containing not more than 0.35 per cent carbon.

There is no question that certain of the higher carbon and alloy steels, when cut with the oxyacetylene process, will develop a thin hardened layer on the torch-cut surface. These same materials, however, require special precautions in welding. Their cutting, furthermore, may be handled by following the same general precautions as employed in welding, namely, either by preheating the edge prior to cutting to prevent the formation of the hardened zone, or reheating following the cutting operation to remove the hardness resulting from the cutting action.

Method of Vertical Welding

By WM. H. T. SVANOE*

THE writer, after years of experiment, has developed a method of "vertical up" welding which he feels will prove superior to methods in general use today. This method is not an imitation of, or a takeoff on any other method—it is something new. Intensive research is going on at the present time to show comparative figures, photographs, photomicrographs, X-rays, etc., and as soon as this material is compiled, another article containing this information will be published.

The writer, in his work as a welding instructor, has taught this method to students now in employment from coast to coast, as well as welders with whom he has been associated during the past five years. The method, or rather welds made by this method have passed government and private tests without any difficulty, but comparative results will be released for the first time in the near future.

The first pass, starting from the bottom, will be applied in the conventional manner—that is—a series of tightly overlapping puddles, each puddle being permitted to freeze before the next is applied. The rod is held perpendicular to the work and is manipulated in a strictly up and down motion, maintaining a short arc at all times. The arc flame moves in a straight line up, no father than necessary to allow the puddle to freeze, and in a straight line down to apply the overlapping puddle.

Succeeding passes using the new method are applied as follows:

A puddle is started at the bottom of the weld, no wider than necessary to obtain the required one-eighth inch or less of metal per pass. The flame is then moved rapidly up and to one side to allow the puddle to freeze, the up motion being no farther than necessary to allow the solidifying of the puddle, and the side motion no farther than the outside limit of the weld. Immediately upon the freezing of the puddle, the arc moves down and across the preceding puddle. Before reaching the outside limit of the weld, the flame is moved up and to the side rapidly, little or no metal being deposited. This up and side motion is taken solely to allow the puddle to freeze. Immediately upon the freezing of the puddle the arc is

* Instructor in Welding.

moved down and across, thus applying an overlapping puddle. The process is repeated to the completion of the pass, succeeding passes being applied in exactly the same manner. Every stroke moves up—in other words, the operator does not rely on piling one puddle on top of the other as in other methods to progress with his weld. The overlapping takes care of itself in this method, the operator consciously moving up with each stroke. Three-sixteenth inch rod will require a step-up of approximately one-eighth of an inch with average amperage, to obtain a maximum of one-eighth inch of metal per pass. To apply less than one-eighth inch of metal per pass, it is merely necessary to increase this "step-up" gap.

In the "down and across" motion, in which the metal is applied, the motion stops before reaching the outer extreme of the preceding pass. The reason for this is that if the arc moves completely across, the flame will remove metal instead of applying it, leaving an undercut. The metal required on the sides of the weld is applied on the down stroke. Anyone familiar with the triangular method knows that to fill the undercuts which occur in this method, the operator must hesitate at the sides of the weld at every stroke to allow the undercut to fill up. It seems logical that if metal can be applied without undercutting, thus obviating the necessity of filling up an undercut, such a method would be more efficient. It would also appear that the possibility of slag inclusions would be considerably less.

In the method described herein, the slag forms most heavily directly down the center of the weld, and is very easily removed. The metal can be applied smoothly with no difficulty whatsoever, which also adds to ease of cleaning of the weld.

The writer feels that the following advantages favor his method:

1. Ease of application.
2. Ease with which specified amount of metal, i.e., one-eighth inch or less per pass, can be obtained.
3. Less possibility of slag inclusions.
4. Ease of cleaning welds.

No claims for superior ductility or physical properties can be made at this time, but results of research under way at the present time will be forthcoming in the near future. The writer can state with assurance that the results are at least equal to those obtained in other methods. Assuming that physical properties are no better than in other methods, the advantages enumerated above are sufficient to deserve the serious study of this method by anyone interested in obtaining the best possible results in vertical welding.

HIGH SPEED WELDING ASSEMBLIES*

By E. W. FORKNER†

THE savings, generally effected by applying resistance welding to a particular fabricating process, obviously tends to promote development of speed in the art of resistance welding. Creating savings, in most conventional operations, generally involves a re-sequencing, which is likely to embrace an additional welding application. Decreased cost may primarily prompt the re-planning of the manufacturing sequence, in this instance, however, in a great number of cases, welding manifests itself in the form of higher quality production.

Spot welding is probably the first method or type of operation that usually presents itself to the average layman's mind, when resistance welding is mentioned. It may be defined as clamping two or more pieces of metal between high conductive alloy electrodes and fusing them with heat created by resistance of electrical current.

One can readily observe that three major factors exist; namely, Magnitude of Current, Time Duration of Current Application and Pressure Exerted on the Electrodes. The writer calls attention to these as being the three interrelated elements which facilitate correlated adjustment to produce the heat required. This heat is determined by the thermal conductivity and fusing temperature of the material to be welded, as related to the cubic displacement of the welded area, plus the loss from non-effective radiation, most of which is absorbed by the water cooled electrodes.

Pressure contributes much toward increasing the area of the weld, hence, the greater the pressure, the greater the amount of current necessary for making the weld. Another important factor is the necessity for quick follow-up with constantly exerted pressure during the period of time that the heated zone of weld is in a state of temperature for fusing.

In all welding applications, the three factors, "Current," "Time" and "Pressure" assumes values as fundamental requisites, and their importance is obviously recognized by all who are engaged in the development of their use. It is generally conceded that the correct combination of values will effect a good welding condition on almost any material, however, extreme difficulty is sometimes encountered in determining the right amount of each. Such facts are usually established from past experience, or through experimental channels.

High speed welding employs all the basic requisites applied to conventional welding practices, in addition to special characteristics, common to high speed welding alone. Most extremely fast multiple spot operations usually require short timing in the order of from one to five cycles of current application for welding, generally, not more than three cycles of "off" time between welds. These repeated short intervals between welds give rise to transient current surges, when non-synchronous timing is employed. A partial solution to this is the use of a specially constructed transformer to decrease the magnitude of the transient surges. The proper solution lies in the use of a synchronous current control device, which provides a balanced flow of current.

The duty cycle, involved in some high speed welding applications, necessitates departure from conventional transformer design, for reasons other than transient current surges. In this instance, the writer refers to the fifty per cent duty as the established standard for design, generally adopted a few years ago by manufacturers

* Presented at Annual Meeting, A. W. S., Chicago, Oct. 23 to 27, 1939.
† Chief Engineer, The Federal Machine and Welder Co., Warren, Ohio.

of resistance welding equipment. In the past, very few applications approached this limit. Today, with extremely fast multiple machines available, and existing high seam welding applications, he not only approaches the permissible duty limit, but in some instances, exceeds it. In this event, the conventional welding transformer would exceed the permissible temperature rise. An over amount of temperature rise will injure the transformer, and any excessive rise whatever results in a certain amount of drawn current being non-effective.

Assuming that proper transformer and current control facilities are available, the high speed machine then involves correct mechanical design. With reference to the multiple spot application, one of the most recent developments is the Ultra Speed method. In this manner, provisions are made for individual secondary circuits—one for each desired place of weld, and also, individual current control. This method features a multiple secondary switch with rolling contact. The latter refers to a water cooled jumper roll, which conducts the secondary current from an accurately machined, water cooled conductor bar, to an adjacent segmented bar. This bar might reasonably be termed a flat commutator assembly. Each commutator segment block is insulated from the ones adjacent, and is connected to its individual welding tip or head by means of a water cooled cable. The jumper roll faces from the solid conductor to the segmented bar, and is screw driven. Its travel range is controlled by the length of the segmented bar, and this length is established by the number of blocks required. Individual cam lobes are so arranged to interrupt the primary current, while the jumper roll passes from one segment bar to the next, and likewise through the entire sequence. A reversing motor starter is provided, so the machine may be re-loaded and weld on the return travel of the roll. The writer mentions the foregoing details relative to the Ultra-Speed method in order to better emphasize the elimination of time delays existent in other methods of conventional welding applications. In doing so, he points to the absence of singular point actuation and calls attention to pressure being applied on all individual points simultaneously. The pressure remains engaged until the completion of the welding sequence, at which time, it is dis-engaged until the repeat operation takes place on the next assembly to be welded. With this method, it is possible to attain a speed at the rate of eight hundred to one thousand spot welds per minute.

Minimized point maintenance contributes to maximum production possibilities in the foregoing method. The pressure may be applied gently, and without appreciable impact in a single closing of the machine involving all points. Very clean welds result from being properly consummated under continued pressure.

A recent development in producing small component assemblies, employing either projection, or the conventional spot welding technique, is the continuous type of machine. It may be described as a pedestal with a non-intermittent rotating disk mounted on top at working height, and sufficiently large in diameter, to meet requirements of the particular application. This platen provides a mounting for several air actuated units of the portable equipment type. The transformer is connected to each of the welding units. It is supplied with primary current through collector rings and brushes. The current control device is initiated by individual cams (one for each unit) on under side of the platen. Water and air are supplied to the various units by means of a turret valve, through the center of the pedestal. Each unit is fitted with a poppet type valve, which engages a stationary master cam at some pre-determined location, approximately opposite the operator's station. A machine of this type is generally equipped with a variable speed drive. The speed with which such a machine can be operated is limited to the speed attained in loading and unloading. With this method, the writer calls attention to complete elimination of time delay for actual welding operation or individual unit function.

Another method of high speed production, which is being used quite extensively by a prominent manufacturer of automobile bodies is the conveyor type of continuous machine. This arrangement features a multiple of fixtures for receiving the component parts involved in a welded assembly—one fixture for each assembly.

The fixtures are mounted on a conveyor, which provides continuous movement. They are constructed in such a manner as to form a means of connection to one side of the transformer secondary, through large brush contacts. The opposite side of the secondary is connected to the adapter containing the welding tip. The adapter is mounted on a double acting welding head, similar to the expansion type of portable equipment, except that it fulcrums at the extreme top, and is free to swing in lateral position, relative to the center line of the fixture travel, when welding pressure is exerted. When pressure is relieved, it is retracted by a return spring. A cam race-way establishes the radial location of the fixtures. In this manner, a multiple of heads may be stationed at various locations about the conveyor, and their action controlled by cams engaging the fixtures.

The various welds are made in station sequence, while the work is in motion, and likewise the loading and unloading. A station is provided for this purpose. Time required to load and unload, together with spot spacing requirements (the latter being controlled by the speed of the conveyor and ability to attain maximum reciprocating action of the air heads) control the production speed of this machine. A speed of approximately fifteen hundred spot welds per minute has been attained by a machine of this type.

There is a recent development, utilizing the projection welding technique in a progressive manner. This machine strongly resembles a tandem set of pinch rolls, spaced about three or four feet apart on a horizontal plane. The first set of rolls may be described as a rotary die set for making the protruding dimples, at required weld locations. The second set of rolls are the electrodes which convey the current and apply the pressure for welding. The welding taking place after a plain sheet is laid on the dimpled face of the one already processed through the first set of rolls. With this type of machine, the almost inconceivable speed of 10,000 spots per minute may be attained. The method is, however, confined strictly to flat stock.

SOME APPLICATIONS OF THE Resistance Welding Process*

By C. L. PFEIFFER†

ALTHOUGH my subject is some applications of the resistance welding process at the Western Electric Company, I cannot resist the temptation to review certain general principles which are often forgotten in our efforts to solve immediate manufacturing problems.

In the past nearly every one who presented a paper on resistance welding stressed the importance of pressure, current, time and their proper coordination in making satisfactory welds. Manufacturers of welding equipment design their equipment to meet very exacting requirements involving these factors and for successive operations of the machine, other conditions being equal, it is possible to duplicate the proper condition time after time.

Occasionally, however, poor welds are made, not due to any unsatisfactory operation of the machine, but due to variables introduced in the weld area. Engineers are becoming more interested in this area and it is gratifying to have papers presented such as those recently written by Studer on "Contact Resistance in Spot Welding," and by Johnson on "Predetermination of Temperatures in Resistance Welding." Dr. W. F. Hess's resistance welding section committee of the Fundamental Research Division is also doing noteworthy work as evidenced by discussions at recent meetings and several papers covering the "Spot Welding of Low Carbon and Stainless Steels." Hensel, Larsen and Holt have also presented some fundamental data in their paper, "Data on Spot Welding of 18–8 Stainless Steel to Yellow Brass." There are others who could be mentioned, but these are representative of the types of papers which are getting at the root of possible difficulties in resistance welding. Investigations along these lines are very difficult of approach and even if an individual investigator accomplishes little, the combined efforts of various men will gradually clarify our thoughts and will eventually make available exact data which should point the way to the solution of many vexing problems.

In order to fully appreciate the art of resistance welding, one should have the proper mental picture of the possibilities in the weld area. Figure 1 shows a simple spot welding circuit in which the weld area stands out for your inspection. There are shown two sheets of material M_1 and M_2 between electrodes E_1 and E_2, the latter connected through large copper conductors to the secondary of the welding transformer. The three points of contact K_1, K_0 and K_2, the material between them and the electrode surfaces are the important factors to be considered in the weld area. Let us consider what normally happens or what might happen at these various points. The current from electrode E_1 flows to sheet M_1 through the contact area K_1; through sheet M_1; from sheet M_1 to sheet M_2 through contact area K_0; through sheet M_2; and from sheet M_2 to electrode E_2 through contact area K_2. It may seem superfluous to many to break down the current path in this manner when one could simply say the current flows from electrode E_1 to electrode E_2 through sheets M_1 and M_2. I feel, however, that each point mentioned should be analyzed separately and, if possible, broken down still further.

The energy required in the weld area is represented by I^2Rt, where I is the current and R is the total resistance from electrode to electrode, and t is the time the current flows. If in making successive welds the energy input into the weld area changes considerably there is at least a possibility of making a poor weld, especially in those materials having a narrow plastic range or having some other characteristic which makes welding difficult. Let us examine each item in I^2Rt and find the greatest possible source of trouble. In view of the many recent improvements in timing equipment, it is possible to get exact timing periods and I should estimate that the accuracy can easily be held to within 1%. Although the current could vary because of a change in contact resistance, there is not much chance of an appreciable change in the average secondary circuit because this value is usually a small part of the total impedance. This leaves only the value of R and it no doubt is the most difficult to control.

It follows that variations in the resistance of the weld area are of major importance and this should be of specific interest to all engineers who are associated with resistance welding. Some of the things to be considered may be listed as follows:

1. Electrode material.
2. Shape and area of electrode contact to be kept constant.
3. Electrode contact area to be kept clean.
4. Electrode contact area to be kept at constant temperature.
5. Resistance of contact area between electrode and part being welded should be same for successive welds.
6. Cleanliness of material being welded.
7. Uniformity in quality and shape of material being welded.

Let us see what happens if the electrode contact area is allowed to become larger because of mushrooming. For example, an electrode tip having a circle contact area $^1/_8$ inch in diameter is used to spot weld $^1/_{32}$-inch material. After a great many welding operations the diameter increases from $^1/_8$ inch to $^5/_{32}$ inch which means an increase in contact area of roughly 50%, or a current drop per unit area of 64%. When the value 0.64 is introduced in our equation

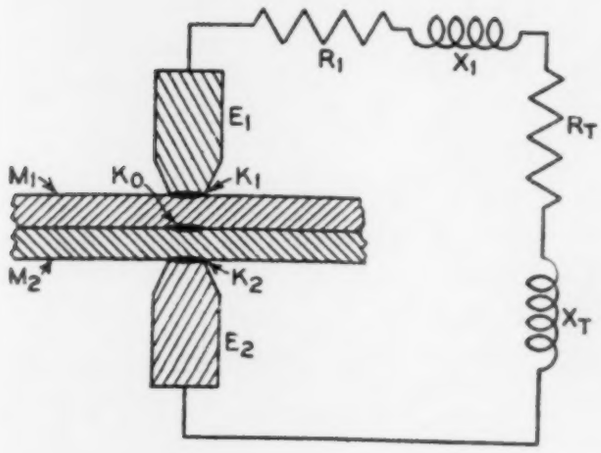
$$\text{energy} = I^2Rt$$

we have $(0.64I)^2Rt = 41\%$ of original.

Figures pertaining to voltage, current and impedance are also helpful in visualizing actual conditions. Let us assume an induced voltage of 5 volts in the secondary of

* Paper presented at Annual Meeting A. W. S., Chicago, Oct. 22 to 29, 1939.
† Western Electric Company, Chicago.

Fig. 1—A Simple Welding Circuit



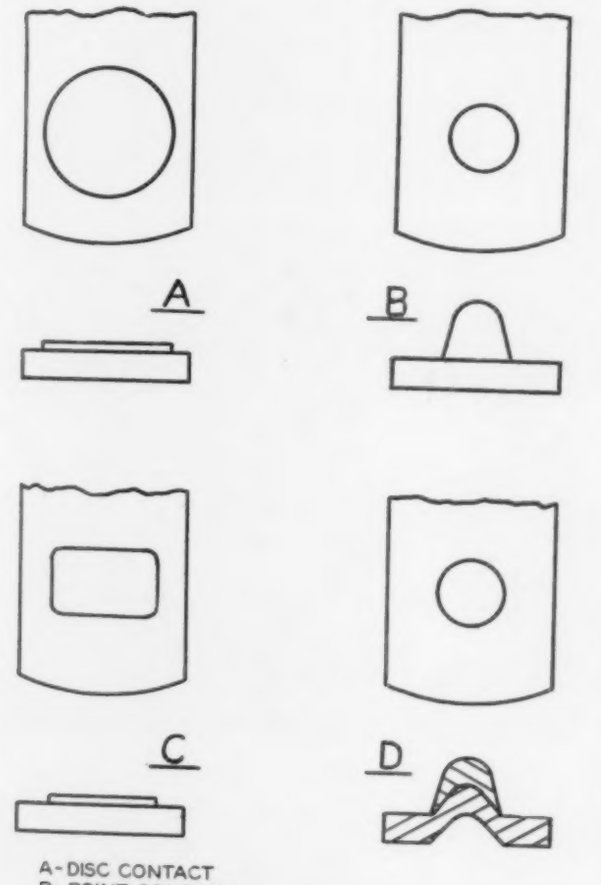
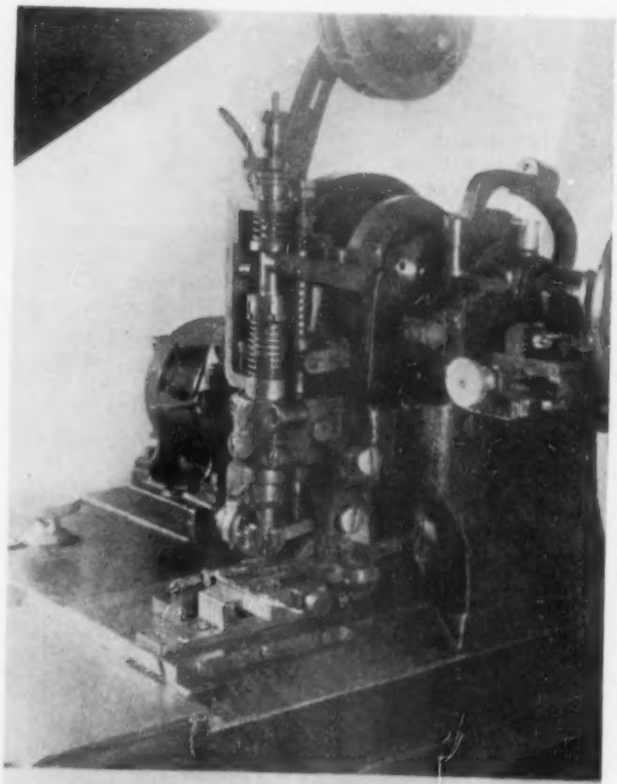


Fig. 2—Precious Metal Point and Disk Contacts

a welding transformer and a welding current of 10,000 amperes. We know that the general equation $E/Z = I$ (volts divided by total impedance is equal to amperes) must be satisfied and that the resulting impedance is $\frac{5}{10{,}000} = 0.0005$ ohm. Picture this value 0.0005: it is the total impedance in the whole secondary circuit, the vector sum of the resistance and reactance. Perhaps the resistance across the weld itself is only 0.0001 ohm. In ordinary electric circuits such small quantities are usually considered negligible.

After these introductory remarks, I feel I am in a much better position to discuss certain essential operations in resistance welding and the problems they represent at the Western Electric Company. In general, parts used in the telephone industry are comparatively small in size and intricately shaped and, because of this, I may overemphasize certain things, but in general I feel our fundamental problems are the same as those of others using this process.

Fig. 3—Semi-Automatic Point Contact Welding Machine



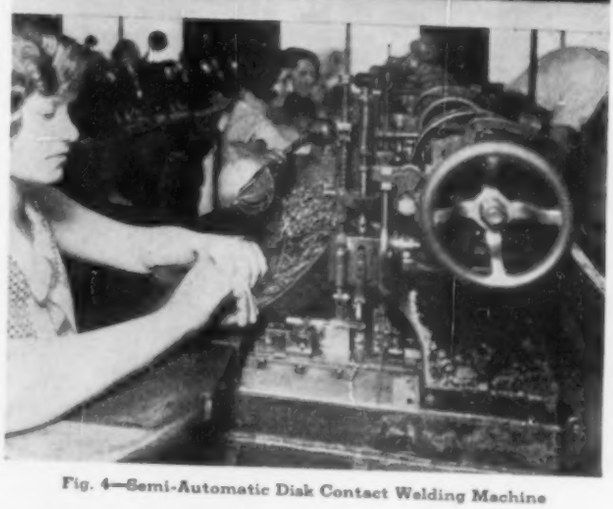


Fig. 4—Semi-Automatic Disk Contact Welding Machine

Probably the most important, in fact the most special use of resistance welding is in the assembly of millions of small precious metal contacts to a variety of apparatus

parts. These contacts are used in many places in the telephone circuit and on their performance depends much of the quality of voice transmission and prompt and dependable circuit control. Figure 2 shows the general forms of point and disk type of contacts, which when mated make up a contact pair. Two each of these two types of contacts are shown, the only difference being in the round or rectangular flat disk contacts and the solid or embossed points. These contacts are very small, the average dimensions for the point being about 0.030 inch in height with a 0.030 inch diameter base while the usual disk dimensions are 0.005 inch in thickness and approximately 0.090 inch in diameter. The welding of these contacts is done on two specially developed machines of similar design having hand-feed reciprocating machanisms for pushing the contact springs under the welding electrodes.

The point machine, shown in Fig. 3, uses the contact metal in the form of wire which is fed to the point of the weld by means of a chucking arrangement. The end of the wire is welded to the contact spring which has been carried into position on a fixture having a reciprocating motion. After the weld is made, the wire is clipped, leaving a certain predetermined length attached to the spring. The spring is moved farther forward in which position the contact is formed with a hammering tool which strikes with sufficient regular force to give the form desired. The spring is then conveyed backward toward the loading position, but is ejected by means of an air jet just before the carrier comes to rest.

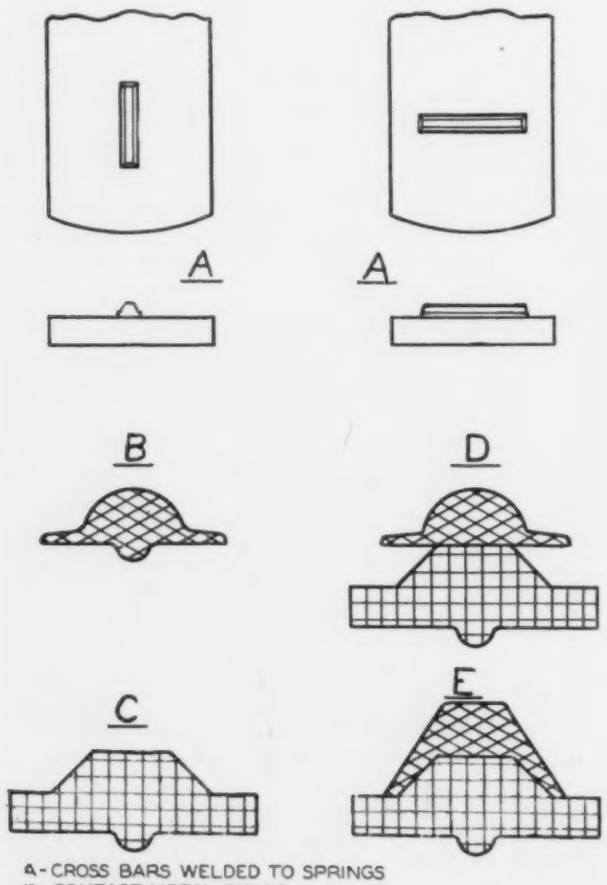
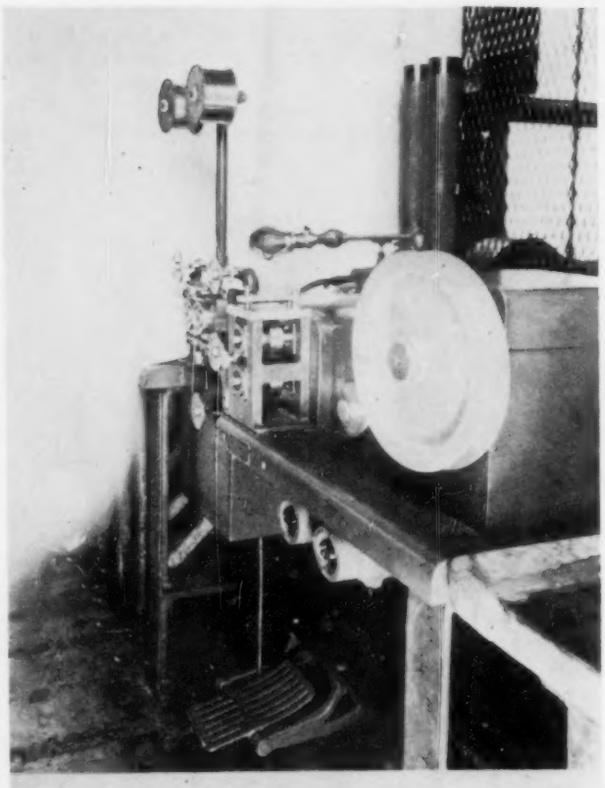


Fig. 5—Crossbar Bi-Metal Contacts

Fig. 6—Bi-Metal Tape Continuous Welding Machine



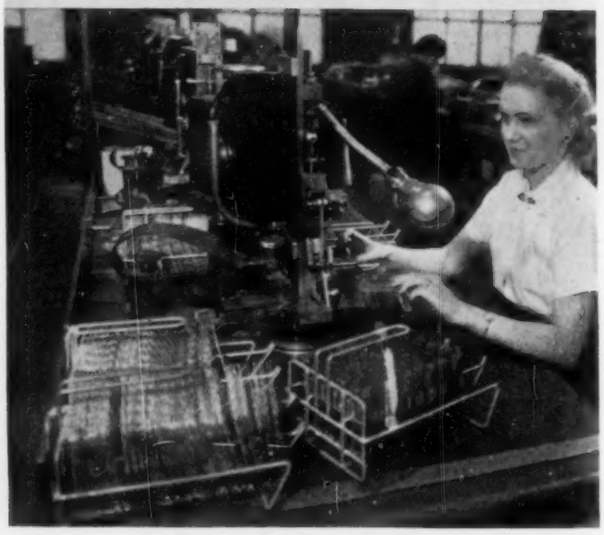


Fig. 7—Bar Contact Welding Head

In the point contact welder as well as on other contact welders which I shall directly discuss, the weld area and the parts being welded are very small. Special care must be taken to have the contacting areas accurate in dimension because a difference of 0.005 inch represents a relatively large per cent of the total. On the point machine the clipping tool cuts the wire uniformly and successively leaves wedge-shaped points of accurate dimensions to contact the spring for the following consecutive welds. Of course cleanliness of all parts fed to contact welders as well as metallurgical and dimensional uniformity is extremely important.

The disk welder, shown in Fig. 4, uses the contact metal in the form of a flat narrow tape which is fed through a blanking tool automatically. After punching

Fig. 8—Butt Welder for 0.011 Permalloy Wire

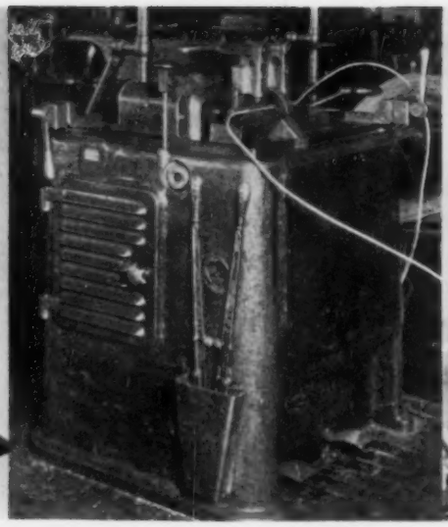


Fig. 9—Copper Rod Welding Machine

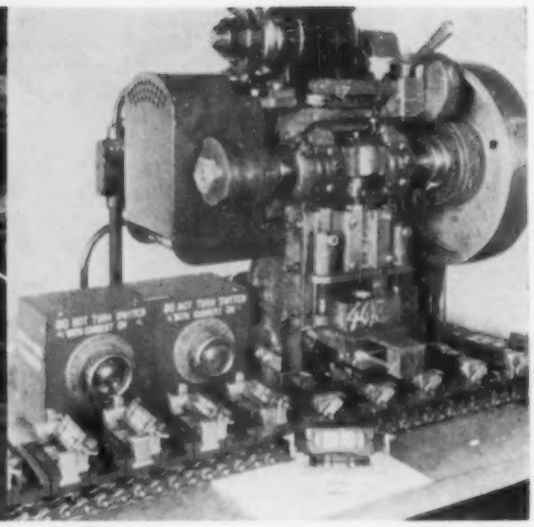


Fig. 10—Switchboard Plug Welder with Chain Feed

out the proper size contact it is carried to the electrodes between two thin metal fingers which grip the disk on its edges. The spring is carried to and from the welding position in a manner similar to the point welder and when it has reached the correct position, the disk moves between it and the electrode. The electrodes then close, holding the disk in position on the spring, the carrier fingers withdraw and the weld is made.

The point and disk welders were developed to replace riveted contacts and resulted in a large saving in precious metal because the shanks of the rivets were completely eliminated. In addition, the handling time was greatly reduced and for these hand-fed machines an output of 1000 to 1500 welded parts an hour is reached, depending upon the shape of the part being fed to the positioning block.

Figure 5 shows a newer contact form known as the bi-metal bar contact. It is made from tape, consisting of an upper layer of contact metal and a lower layer of base metal. The cross sections *B*, *C*, *D* and *E* illustrate how this bi-metal is produced. The two tapes are welded together on a roll type welder to the shape shown under *D*, the current being localized in the welding ridge on the lower side of the contact metal tape. After the welding operation, the bi-metal tape is passed through rolls and given the final shape, shown by *E*. The bi-metal tape is automatically fed into a machine which cuts it to the required bar length and welds it to springs in positions shown by *A*.

The special continuous roll welding machine for producing this tape is shown in Fig. 6. It consists essentially of two heavy grooved copper electrode rolls for feeding the two tapes into the welding position. The axis of one roll is fixed while the other is pivoted in such a manner that it corresponds to the movable electrode in a conventional spot welder. Current is fed to the rolls through graphite brushes, similar to most low voltage generator brush designs. Pressure for the welded joints is regulated by means of a very sensitive spring adjustment and the whole of the movable electrode is delicately balanced in order to respond readily. The bi-metal is produced at the rate of about 8 ft. per minute and a separate weld is produced for each half-cycle of 60-cycle current supply.

Although the development of the bi-metal shape introduced some very definite advantages, it also introduced some rather difficult welding problems which were mainly a matter of material and sizes of sections. For instance, extensive development revealed that a pure nickel base metal of the shape previously shown was most desirable for making the tape and for welding to spring assemblies. In addition to several cross sections of bi-metal bars, some heavier solid bars of palladium and pure silver are welded to nickel-silver and brass springs. As you know, the problem of welding dissimilar metals and high conductivity metals is often difficult of solution. We are, however, able to weld these metals and peculiar shapes at a high rate of speed on a production basis with very little trouble

The machine for welding bar contacts to various shaped springs is shown on Fig. 7. This machine feeds the bi-metal contact tape through a guide channel into a cutter and pusher mechanism which shears off the proper length of bar contact, pushes it into position between a grooved upper electrode and contact spring immediately after which the parts are welded. Although this machine is equipped with a manually operated carriage for welding one or two adjacent contacts, it may be adapted to various types of feed depending on the type of job so that it is semi- or even fully automatic.

It may be of interest to note two other operating procedures followed on our contact welders. For electrodes we use both copper and some of the well-known electrode alloys. In each case the alloy used was determined experimentally and was desirable because of the shape of

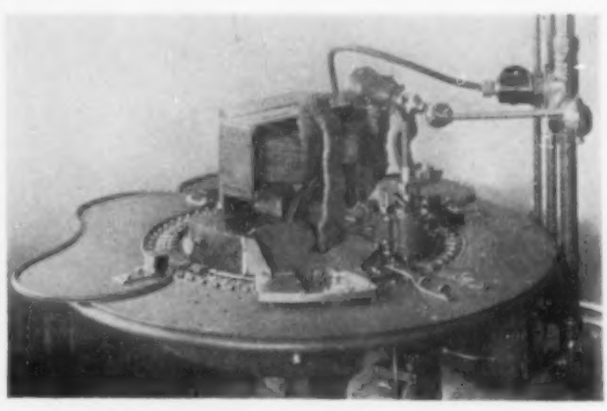


Fig. 11—Contact Spring Welder with Dial Feed

or the material in the part being welded. Copper is used principally for large flat electrodes which contact a spring side opposite to that to which a contact is welded. For a timer we use a mechanically adjustable cam arrangement directly geared to the main drive shaft of the machine and most welds are made in two or three cycles. Oscillograms show no outstanding transients and an unbelievable uniformity in length of time the circuit is closed. No doubt, the use of low current values under 50 amperes at 440 volts in the primary and a very quick break make such performance possible.

Figure 8 shows a rather unusual application of butt welding, in which the welding is done under carbon tetrachloride. This operation was required when welding 0.011 permalloy wire because when welded in air, the joints were brittle and unsuited for subsequent operations. A specially constructed light butt welder was built and equipped with jaws made of monel metal to prevent corrosion. The right jaw is movable and actuated by a vertical blade spring. The secondary circuit has a resistance ballast in series with the welding jaws which serves as a timer, a current tapering device and an auxiliary annealing circuit. The resistance unit has a low variable resistance in parallel with a pure nickel fuse wire. The wire ends are clamped in the welding jaws, immersed in carbon tetrachloride by raising the container to the jaws, and the current sent through the circuit. The resistance is adjusted so that the nickel fuse blows when the weld is completed and the current is reduced to allow an annealing current to flow as long as the welding key is depressed. In a separate operation, the welding wire is placed in the annealing terminals shown at the extreme top of the photograph and annealed for a distance several inches on either side of the weld. The joints are very strong and, after the welding flash is removed, may be drawn through wire-reducing dies. Small nichrome, chromel, perminvar, and iron and constantin thermocouple wires can easily be joined on this machine.

Figure 9 shows a specially constructed copper rod welder in use at the Western Electric Company and other wire-drawing plants. The operation of these machines is similar to most butt welders. High current densities ranging in value from 0.2 to 0.4 ampere per circular mil and, applied for relatively short intervals of time, are used to make joints suitable for drawing. Rod ends are cut square by means of a circular saw mounted at the left of the machine. The stationary and movable jaws

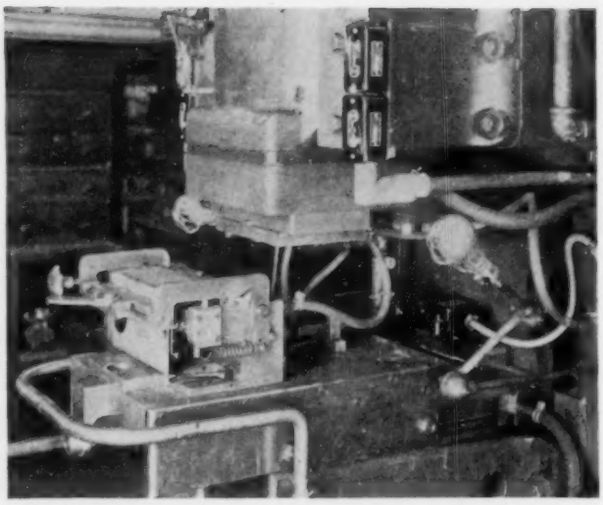


Fig. 15—450 Kva. Press Welder with Sliding Safety Bolster Plate

are of aluminum-bronze of very sturdy construction. Long clamping arms give a good leverage and make for good contact between the rod and copper die blocks. The movable jaw slide is accurately fitted and leads thereto are mounted carefully in order to have the jaw movement properly coordinated with the heating cycle during the welding operation. Although the butt welding of copper was the first thing Thomson did back in 1886 when he discovered this process, its use in the wire-drawing industry dates back to approximately ten years ago. It seems that before that time the quality of copper butt welds was not suitable for withstanding passage through wire-reducing dies. Here is a perfect exam,·le of the proper coordination of current, pressure and time.

The next four figures show machines where large quantity production makes it essential to have fast feeding loading devices. Figure 10 is a punch press type machine for welding switchboard plug centers, samples of which are shown in the foreground. The outstanding feature of this machine is the chain used for bringing the welding fixtures into position. Two separate joints are made in each fixture by two transformers separately controlled and adjusted by timing cams and rotary tap switches, respectively. The press mechanism and fix-

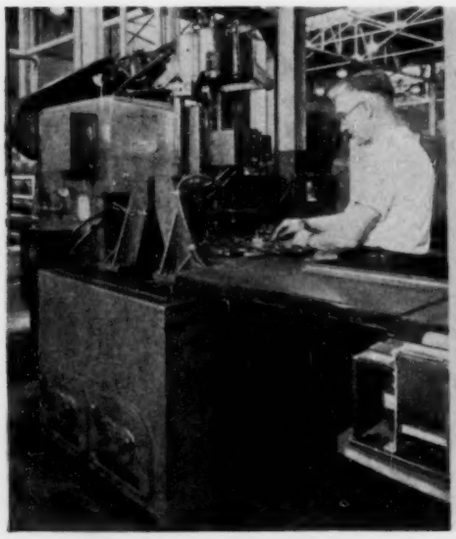


Fig. 12—Dial Feed Magnet Welder

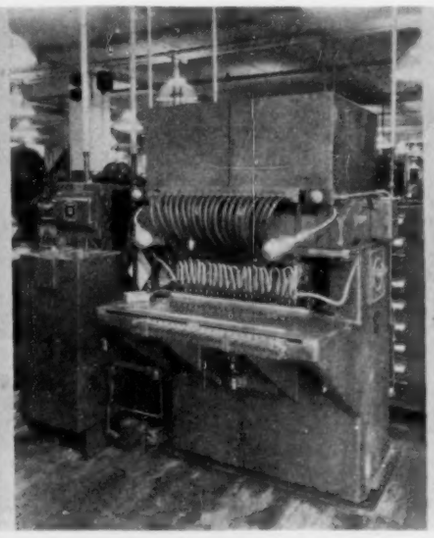


Fig. 13—Twenty-Head Hydromatic Welder

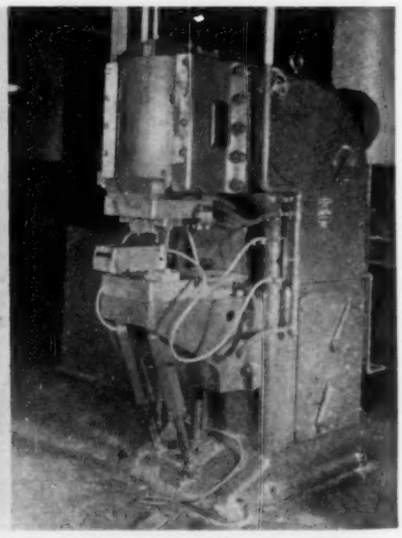


Fig. 14—450 Kva. Press Welder

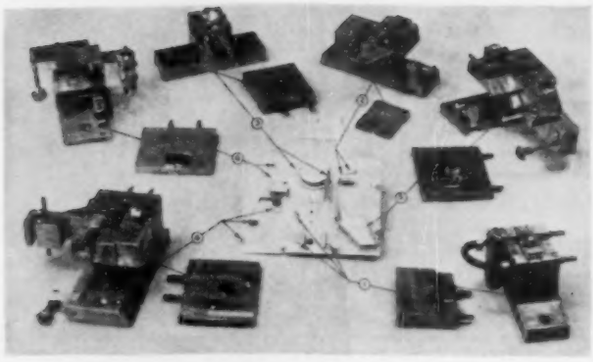


Fig. 16—Tools for Welding Miscellaneous Parts in Steel Housing

tures are split so that separate pressure adjustments may be had for either joint.

Figure 11 shows a dial feed welder for welding a small bronze part to a nickel-silver part at two points. One junction is a projection weld and the other a butt weld. The two parts are inserted in small holders on the rotating dial and advanced successively under two separate welding heads, one for each weld. Each head has its individual electrodes, pressure system, transformer and control. This is a high-production machine, its output being limited by the rate at which parts are correctly placed in the holders.

Figure 12 shows a dial feed welder for joining cobalt steel and permalloy members. The welding of this assembly was considered difficult because of the properties of the two materials. Magnet steels become more embrittled after welding and the permalloy is a high-resistance material with a narrow mush range. It is a well-known fact that difficulties are less apt to occur when only one weld is made at a time. This machine makes four welds simultaneously, but follows the one weld at a time idea because it is really a four-head spot welder which makes four individual spot welds. There are four separate transformers and regulators connected to four separate upper electrodes, all insulated from each other. Each electrode has a separate air cushion pressure mechanism. The timer mechanism is common to the four transformers. Individual fixtures which hold the parts to be welded are placed in the dial slots while it rotates at about 30 r.p.m.

Figure 13 is a 20-head hydromatic welding machine used for welding small studs less than $^1/_8$ inch in diameter to 0.060-inch steel strip. The loaded fixture is placed under the welding guns and after the starting buttons are pressed, the machine automatically makes a total of 20 welds in rapid succession. The machine has two transformers, 10 guns being connected to each one. The guns from each transformer are paired so that the electronic timer fires 10 times for each complete cycle in welding one strip. The material in this case is not difficult to weld, but because we did not think it feasible to weld twenty studs simultaneously in a parallel circuit, the one at a time principle was resorted to and rapidity obtained by using rapid operating hydromatic guns. It may be of interest to know that the electrodes' tips on this machine are kept as cool as a cold water pipe and have made over 4,000,000 welds without having been replaced.

The largest resistance welders in our plant are rated at 450 kva. Figure 14 shows one of these welders with a tool set up for welding an angle bracket to the inside of a sheet metal housing. Inasmuch as the loading of these machines is comparable to placing parts in a punch press, the problem of safeguarding the operator has given us much concern. We feel that the problem has been solved satisfactorily with the installation of a lower bolster plate which automatically moves the tool in and out from under the ram of the press before and after each welding operation is performed. Figure 15 shows the features of this mechanism. We have found that the small amount of time lost due to the movement of the bolster in and out of the welding position is more than offset by the ease of loading in the open.

Figure 16 shows the tools required for projection welding miscellaneous parts to the inside of a steel housing. With these tools, six welding operations and a total of twenty-six projections are required. If this assembly were made up with individual spot welds, forty-six joints and forty-six welding operations would be required.

Figure 17 shows a 100 kva. press type welder used for assembling a horseshoe-shaped magnet steel part to a low carbon steel mounting plate. Due to space requirements, welding provided the only possible method of economical assembly.

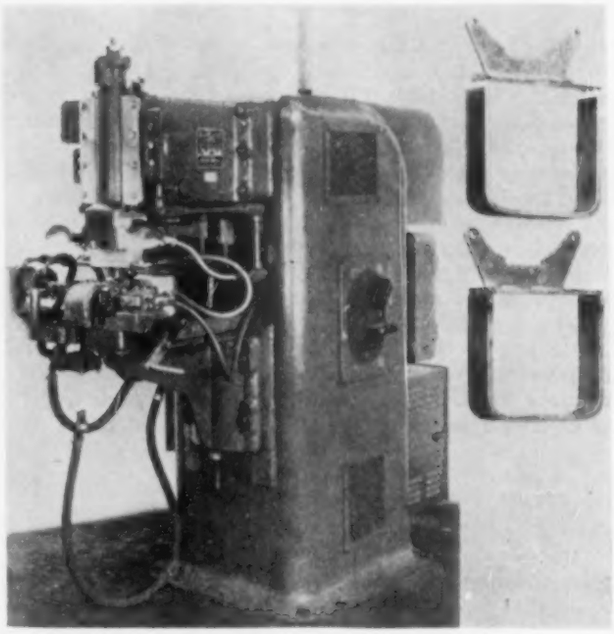


Fig. 17—100 Kva. Magnet Welder

Although our many assemblies are peculiar to the telephone industry, I do not believe our problems are different than any large shop using resistance welding. Although many jobs require individual analysis because of shape or materials, the same principles are involved and the same difficulties arise as in other industries. The design of some of the machines indicates what is being done to offset possible variables in the region of the weld, but our principal problem is to find out more about this area in both a qualitative and a quantitative sense. It follows that we should spare no effort in encouraging fundamental research because only through complete understanding of fundamentals can we as engineers hope to develop the tools to solve our welding problems of today and tomorrow.

JOINING WIRE MESH

By C. C. NOTEBAERT*

STRONG joints in wire screen, with mesh as fine as 76 to the inch, can be made consistently by means of the oxyacetylene flame. When the proper silver-soldering technique is employed, such joints are hardly apparent to the naked eye.

CLAMP JIG REQUIRED

One of the first requirements for satisfactory soldering of wire screen is a suitably designed jig. Basically, as shown in the sketch, this consists of three pieces of steel plate, two of which are beveled along one edge. One large plate serves as a supporting base for the two pieces of screen which are to be joined. When the edges of the wire mesh have been lined up, the beveled plates are placed in position as shown, and serve to hold the screen securely during the silver-soldering operation.

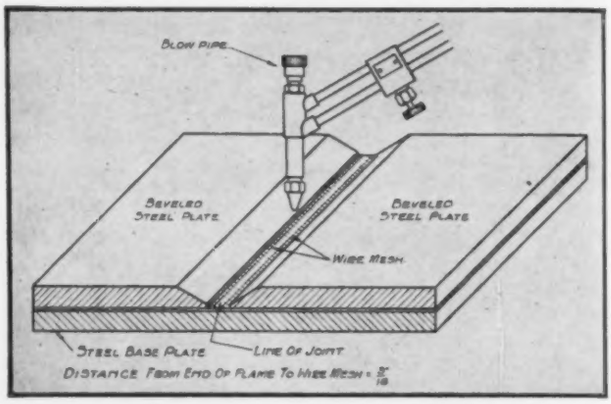
For production work of this nature, quick-acting clamps should be permanently installed so as to speed the positioning of the wire mesh and beveled clamping plates. Some jigs of this type, which have already performed satisfactorily over a period of several years, measure overall only 10 in. by 18 in., but the actual size of the jig is, of course, determined by the work to be done.

JOINT PREPARATION

As for all silver-soldering, the edges to be joined should be thoroughly cleaned first, either by mechanical or chemical means. While it is possible to use emery cloth for this purpose on the coarser screens, it will be of advantage to swab the finer meshes with an acid solution followed by a rinse. It is necessary to clean only the immediate area of the bond—never more than one inch on either side of the joint. If there is any question regarding the desirability of cleaning, make a test with a small piece of scrap wire mesh. Obviously, if the silver solder adheres and flows properly, there is no need for further cleaning.

FLUXING IMPORTANT

Once cleaned, the edges to be joined should be fluxed thoroughly on both the bottom and top surfaces of the screen as well as around the circumferences of the individual wires. A solution is prepared by dissolving the flux in boiling water. It is difficult to recommend the exact proportions for this mixture because the strength of the flux solution is dependent upon the composition and condition of the wire gauze which is to be joined. It is a good general plan to start with a mixture consisting of one can of flux to one quart of water. Actual experiment then will determine whether a stronger or weaker solution is preferable, and proper additions of flux or water can be made as needed.



A Properly Designed Jig Is Essential for Successful Joining Wire Screen by Means of the Oxyacetylene Flame

FLUX CONTAINS SILVER SOLDER

In actually joining the wire mesh, the silver solder cannot be used in strip or rod form if strong, neat joints of consistently high quality are desired. Instead, solid stock should be finely divided by filing with a fine or smooth file. The silver solder filings are then added, in proper amount, to the water-mixed solution of flux, and the whole is mixed thoroughly together. Application of the metal-containing flux to the joint, as previously described, is accomplished by means of a fine camel hair brush. Only a very narrow band is applied along the area to be joined.

JOINING

When the screen or wire mesh has been carefully cleaned, fluxed and lined up in the jig, the joint is completed by means of the oxyacetylene flame. Because the screen wire is very fine gage, it is essential that the flame used be very small and highly concentrated. Small air-acetylene torches, also airplane or sheet metal welding, or lead-burning blowpipes, with No. 0 welding heads or tips, provide highly satisfactory flames for this type of work.

BLOWPIPE MECHANICALLY OPERATED

Short joints can be made by hand, but the best method of producing an even joint of any considerable length is to fix the oxyacetylene blowpipe or air-acetylene torch

* The Linde Air Products Company.

in a traveling jig. When the flame is properly adjusted and mechanically operated, a uniform speed can be obtained which will insure proper bonding of the parts without melting or burning the wire base metal. This burning tendency can be controlled to a great extent by constantly maintaining the tip of the flame close to the work. Best results are obtained at a distance of about $^3/_{16}$ in.

Only the heat of the soft, concentrated flame is utilized in making the bond. Care should be exercised to prevent actual contact of the flame with the silver solder since such contact, as well as application of an excessive amount of heat, will cause the joint to be weak and porous.

Some operators find it desirable to hold the blowpipe or air-acetylene torch at an angle to the work. This, however, must be determined experimentally by the individual. In any event, if it is at all possible, it is advisable to complete each joint without removing the heat of the blowpipe flame from the work once the bond has been started.

The MECHANICAL and PHYSICAL Properties of Weld Metal

By W. D. WALCOTT*

PREFACE

This investigation was undertaken by the research subcommittee on arc welding of the Ontario Hydro-Electric Power Commission as part of their research activities for 1939.

The purpose of the investigation was to obtain a comparison of the mechanical properties of the weld metal deposited by those electrodes which are most frequently used by the manufacturers of welded equipment in Canada.

IN order to assess the quality of the weld metals deposited by the various electrodes, several different types of tests were employed. These included a determination of the tensile strength, yield point, elongation, reduction of area, Charpy notched-bar impact values and, in the case of a few electrodes, the fatigue limit.

The adoption of this rather comprehensive testing scheme is based on the fact that the service performance of welded metal cannot be appraised on the basis of the results obtained from one type of test. Since welds, as a part of fabricated structures, must in some cases withstand impact or suddenly applied loads, and in other cases resist stresses of a repetitive nature, it is essential to subject weld metal to impact and fatigue tests. Although the figures obtained from these tests are not directly applicable to design problems, they give a definite indication as to whether or not the material is sound and possesses the qualities required to assure satisfactory performance under dynamic loads. Equally important, from the designer's point of view, are the results obtained from the conventional static test which give a direct measure of the ductility of the weld metal and a value for its yield point, which, if the dynamic properties of the material are satisfactory, may form the basis for the determination of the allowable working stress.

METHOD OF TESTING

Two welded test-pieces, similar to that shown in Fig. 1, were made up using each of the nine electrodes to be investigated. Each test-piece consisted of two mild steel plates $12^1/_2$ x 3 x 1 inches chamfered at 45° on one edge. These plates were separated by $^1/_8$ inch, tacked together and welded in the downward position by several passes. Each pass of deposited metal was thoroughly scaled before the next layer of metal was deposited.

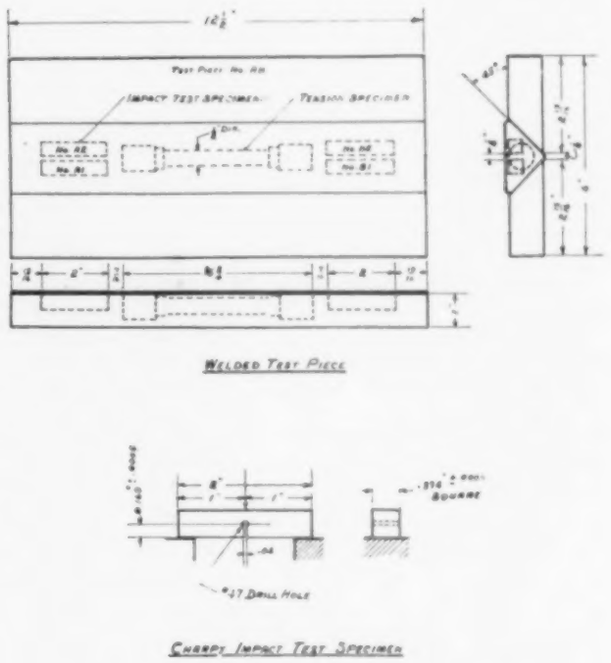


Fig. 1 - Location of Specimens Removed from Welded Test Pieces

All of the electrodes used were $^3/_{16}$ inch diameter and were of the shielded arc type.

The test-pieces were all made by the same welder. The welder was instructed to take no special precautions in the preparation of the test-pieces, but rather to use the same technique as would be employed in ordinary shop work. As a result of these instructions we believe that a more usable comparison of the electrodes was obtained than if a special technique, which might not be rigidly adhered to under production conditions, had been used. This may explain why, in some cases, the values obtained in the present investigation differ from

* Ontario Hydro-Electric Power Commission Laboratories.

those which appear in the manufacturer's literature.

One tension and four impact specimens of all-weld metal were removed from each of the nine test-pieces in the as-welded condition. Six of the corresponding test-pieces were stress relieved at 1100° F. for two hours and furnace cooled before removal of the tension and impact weld specimens. The purpose of the tests on the latter specimens was to determine the effect of stress-relieving temperatures on the physical properties of the weld metals. The three remaining test-pieces were left in the as-welded condition and a sufficient number of all-weld-metal fatigue specimens were removed from each to determine the fatigue limit of these materials.

The location in the test-pieces from which the tension and impact specimens were removed is illustrated in Fig. 1. Due to the one-inch-plate thickness adopted it was possible to obtain standard one-half-inch A. S. T. M. tension specimens, full-sized Charpy notched bars and Avery fatigue specimens.

In the case of one pair of test-pieces, namely, *AB-W* and *AB-S* in the as-welded and stress-relieved conditions, respectively, the cross section of the weld and the adjoining parent metal was surveyed for hardness in an attempt to detect any change in this property which might have occurred in the heat-disturbed area adjacent to the weld deposit.

TEST DATA

A summary of the test data including the specific gravity, ultimate strength, yeld point, percentage elongation, percentage reduction of area and Charpy notched bar impact number of the deposited weld metal from each electrode is recorded in Table 1.

For comparative purposes certain of the data are presented graphically in Figs. 2, 3 and 4.

Table 1 also includes the endurance limits of the weld metals deposited from three of the electrodes.

Figure 6 shows the fractured tension specimen and a typical impact specimen from each test piece. It will be observed from the photograph that the tension specimens *OP-W* and *GH-W* show no indications of included foreign matter and broke with a cup-shaped fracture

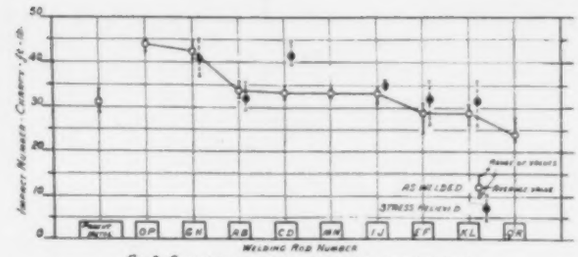


FIG. 2—COMPARISON OF IMPACT NUMBERS ON ALL WELD METAL

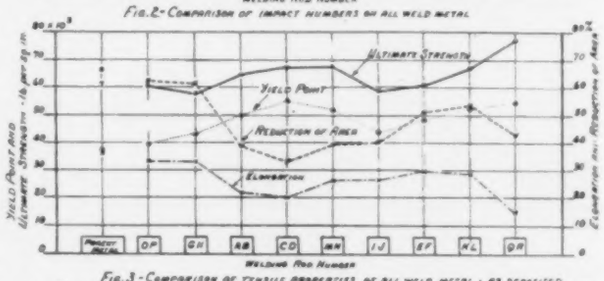


FIG. 3—COMPARISON OF TENSILE PROPERTIES OF ALL WELD METAL—AS DEPOSITED

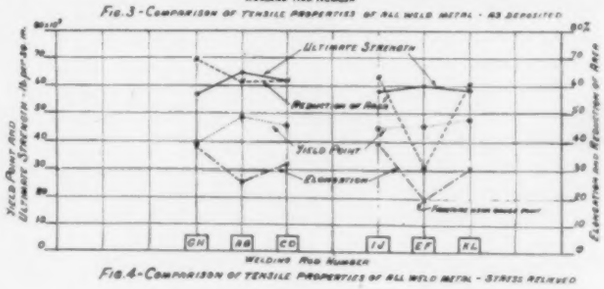


FIG. 4—COMPARISON OF TENSILE PROPERTIES OF ALL WELD METAL—STRESS RELIEVED

which is indicative of high ductility. The specimens from the remaining test-pieces all revealed some evidence of slag inclusions. Specimen *QR-W* was particularly objectionable in this respect.

IMPACT VALUES

In Fig. 2, the weld metals are classified in order of their notched bar impact numbers. The metal deposited from electrodes *OP* and *GH* give impact numbers which are

Table 1—Mechanical Properties of Weld Metals

Welding Rod Number	Tensile Properties: Ultimate Strength Lb. per Sq. In.	Yield Point Lb. per Sq. In.	Per Cent Elongation 2 In. Ga. lg.	Per Cent Reduction of Area	Impact Number Ft.-Lb.-Charpy Keyhole Notch: 1	2	1	2	Av.	Endurance Limit Lb. per Sq. In.	Specific Gravity Av. of 8 Specimens
*AB-W**	65,000	50,000	22.0	38.5	21+	36	15+	32.5	34.2		7.816
*AB-S**	64,300	48,800	26.0	61.9	34.5	35.5	33.5	29.5	33.2		
CD-W	67,100*	54,900	20.0	32.6	15+	22+	33	32.5	33.7		7.836
CD-S	61,800	45,700	32.5	62.0	45	42	42	40	42.2		
EF-W	61,300	49,100	30.0	51.1	24	31	30	30	28.7		7.853
EF-S	60,000*	45,400	20.0	31.7	31	34	26	36	31.7		
GH-W	57,800	42,900	33.0	60.8	41	45	43	41	42.5		7.857
GH-S	56,900	39,400	39.0	69.6	45	42	37	43	41.7		
IJ-W	58,400	43,800	26.5	40.0	31	33	34	35	33.2		7.852
IJ-S	59,000	44,200	38.0	62.9	34	36	36	34	35.0		
KL-W	66,900	52,400	29.0	53.8	30.5	26	28	29	28.4		7.838
KL-S	58,500	47,800	31.0	60.5	33	26	36	31	31.5		
MN-W	67,500	52,200	26.5	39.1	33.5	33.5	33.5	34.5	33.7	21,000	7.826
OP-W	60,200	39,900	33.0	62.3	45	44.5	44	43	44.1	20,000□	7.860
QR-W	73,600*	54,600	15.0	42.5	23	27.5	23	23	24.1	22,000	7.826
Parent Metal	66,000	37,100	36.0	61.5	32	28.5	34	30	31.1		

* *W* = As-welded. *S* = Stress-relieved, two hours at 1100° F., furnace cooled.
* Poor fracture showing a large number of slag inclusions.
\+ Impact result discarded—slag inclusions located on notch.
□ Fatigue limit indefinite. Material appeared to be non-uniform in fatigue resistance.

some 40% higher than those of the parent metal. The impact numbers of the weld metals deposited by the other electrodes are of the same order as that of the parent metal, with the exception of that obtained from electrode *QR*, which gave values which were consistently low.

DUCTILITY

In Fig. 3 it will be observed that the elongation and reduction of area of the weld metals deposited from electrodes *OP* and *GH* are of the same order as the corresponding values obtained on the parent metal. The ductility of the weld metals from the other electrodes are somewhat lower than this. Considering the static properties of all of the weld metals which were tested it will be noted that high ultimate strength and yield point are generally accompanied by low ductility. Since, in the case of all the weld metals, the yield point is greater than that of the parent metal, it would appear that nothing is to be gained by increasing the strength of the weld metal above that of the parent metal at a considerable sacrifice in ductility. A good example of this is the weld metal deposited from electrode *QR* which, although it has a much higher ultimate strength and yield point than the parent metal, is very much less ductile when tested under static or impact loads.

EFFECT OF STRESS RELIEF

A comparison of the data presented in Figs. 3 and 4 shows that stress relieving of the weld metals, in the majority of cases, lowers the ultimate strength and yield point by a few per cent. This slight decrease in tensile strength, however, is accompanied by a considerable increase in ductility, as revealed by a higher percentage elongation and reduction of area. The stress-relieving treatment appeared to have little influence on the impact values of the weld metals.

HARDNESS VALUES

The results of the hardness survey across the faces of the as-welded and stress-relieved test-pieces made with electrode *AB* are shown graphically in terms of both the Vickers and Rockwell scales in Fig. 5. It will be observed that there was very little difference in hardness between the deposited weld and the parent metal. No hard spots were found on the line of fusion and, in fact, the hardness along this line was some 15 points lower on the Vickers scale than the material at the center of the weld. The metal at the top surface of the weld, which was applied in the last pass and therefore was not subjected to reheating and consequent grain refinement by succeeding passes, was some 40 points harder on the Vickers scale than the parent metal and some 25 points harder than the material at the center of the weld. The progressive increase in hardness along the center line, from the bottom to the top of the weld, is a good illustration of the grain refinement effected by multiple bead deposition. Further, it should be noted that stress relief at a temperature of 1100° F. brings about a decrease in hardness of the weld metal which is most pronounced in the very hard layer near the top of the weld.

CONCLUSIONS

1. The weld metals deposited from all of the electrodes which were tested, with one exception, namely, *QR*, gave notched bar impact numbers which were equal to or higher than those obtained on the structural steel plate.

2. The yield point of the weld metals was higher in every case than the yield point of the parent metal.

3. Subjecting the weld metals to a stress-relieving temperature of 1100° F. brought about a slight diminution in ultimate strength, yield point and hardness, accompanied by a small increase in elongation and reduction of area.

4. The material deposited by electrodes *OP* and *GH*, in the as-welded condition, showed a reduction of area and elongation which was practically equivalent to that of the parent metal. The ductility of the materials deposited from the other electrodes, in the same condition, was, in the majority of cases, considerably lower than that obtained on the parent metal.

5. The highest impact values and the best static properties were obtained on those weld metals, *OP* and *GH*, which had the highest specific gravity and showed no visual evidence of included foreign matter. The weld metals deposited from the other electrodes all revealed the presence of included slag, which may have been caused either by incorrect melting procedure or undesirable characteristics in the coating, which inter-

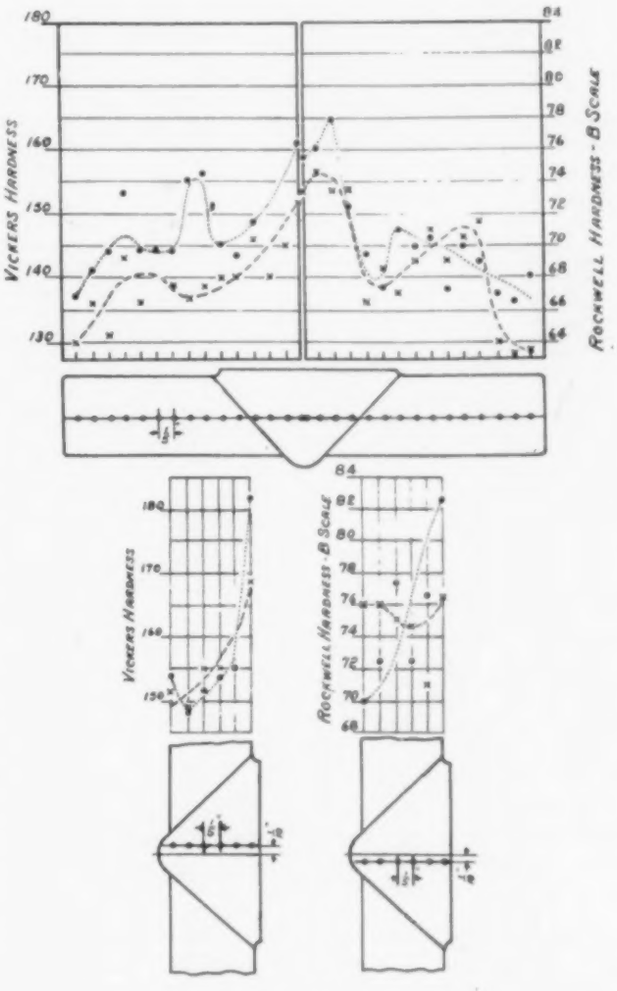


FIG. 5 - HARDNESS VALUES ACROSS WELDED TEST PIECE

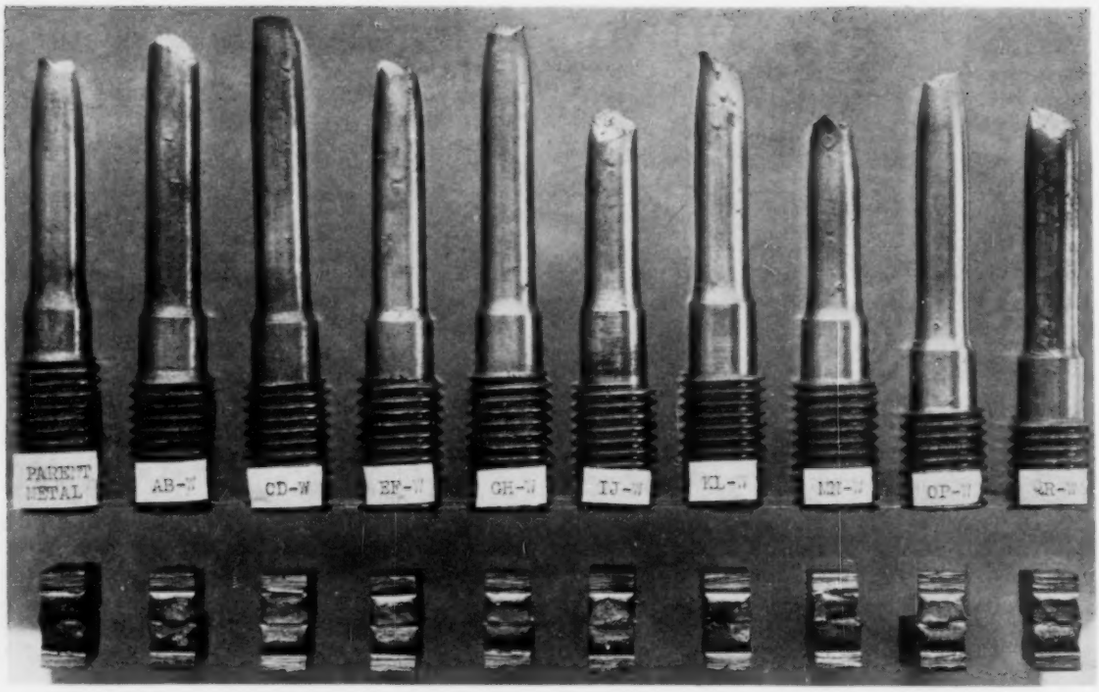


Fig. 6—Fractured Tension and Impact All-Weld Specimens

fere with its complete volatilization. Electrode *QR* was particularly objectionable in this respect, the deposited metal being dirty, porous and having a very low specific gravity.

6. The impact test furnishes a simple method of comparing the quality and homogeneity of weld metal. High impact values are always associated with high ductility, as revealed by the elongation and reduction of area in the static test. Consistency in the impact results indicates homogeneity of the weld metal, a quality which is very difficult, if not impossible, to assess on the basis of tension tests alone.

7. The consistency of the results obtained in a series of impact tests on a number of all-weld-metal specimens removed from a test-piece, such as that used in the present investigation, is a reliable index of uniformity and for this reason could be employed as a qualification test for welders.

8. In the case of some of the electrodes tested the ultimate strength of the deposited metal, as published in the manufacturer's data, is considerably higher than the values which we obtained. This discrepancy may have resulted from a difference in the plate thickness or size of the electrodes use. It is also possible that the manufacturer's figures were based on test-pieces welded under very carefully controlled conditions, whereas the test-pieces used in this investigation were prepared under the same conditions as those employed in commercial welding.

RECOMMENDATIONS

The information obtained in the investigation reported above forms the basis for the following recommendations:

(*1*) *Electrode Quality Test*

The insertion of a clause in standard arc-welding specifications stating that, where deemed necessary, the inspector may require the manufacturer to prepare a welded test-piece similar to that shown in Fig. 1. The impact numbers obtained on all-weld-metal Charpy specimens removed from any part of the weld, in the above-mentioned test-piece, shall be at least 30 ft.-lb. If the impact numbers are consistently lower than 30 ft.-lb. the electrode shall be considered unsatisfactory and replaced by one which meets the above requirements.

(*2*) *Qualification of Welders*

The insertion of a clause in standard arc-welding specification stating that, where deemed necessary, the inspector may require a welder to prepare a welded test-piece similar to that shown in Fig. 1. The impact number obtained on all-weld-metal Charpy test specimens removed from any part of the weld in the above-mentioned test-piece shall be at least 30 ft.-lb. If the impact numbers are consistently lower than this, or, if, in the inspector's opinion, they are not sufficiently uniform, the welder shall be considered to have failed to meet the qualification test.

ACKNOWLEDGMENTS

In conclusion the author would like to thank the various manufacturers who market welding rod in Canada for their cooperation in furnishing the electrodes, used in this study, free of charge.

Acknowledgment is also made of the assistance rendered by Mr. D. G. Watt, of the Laboratories of the Hydro-Electric Power Commission, who gave valuable help at all stages of the investigation.

ATOMIC-HYDROGEN ARC WELDING

Solves Difficult Problems*

By W. E. WILSON†

THE atomic-hydrogen process of welding differs from the ordinary arc-welding process in two respects: first, the arc is maintained between two electrodes rather than between one electrode and the work, and, second, the arc is made to occur entirely in an atmosphere of hydrogen to produce atomic hydrogen which with the arc is directed on the work to perform the welding operation.

THE HYDROGEN ATMOSPHERE

The hydrogen atmosphere excludes all oxygen and other gases which might combine with the molten metal to form oxides and other impurities; and, in addition, it is so active in its atomic condition that it successfully removes oxides that might have previously formed on the surface of the work. Also, the recombination of the hydrogen from atomic to molecular state results in a high-temperature arc fan and especially good heat transfer. Because the arc used to generate atomic hydrogen is independent of the work and can be moved instantly at will, it provides an unusually mobile tool which is especially valuable in the fusion welding of delicate and exacting work. Although the arc is ordinarily maintained constant while welding, it can be adjusted over a wide range of size and intensity to provide a wide choice of heat to suit a wide variety of work. As the result of all these characteristics, metal that is properly fused by atomic hydrogen is uniform, dense and free from pinholes, and the welded joints are especially ductile, strong and smooth in appearance.

* Reprinted from October, 1939 issue of General Electric Review.
† Industrial Department, General Electric Company.

Fig. 1—An Atomic-Hydrogen Arc-Welding Equipment in Use

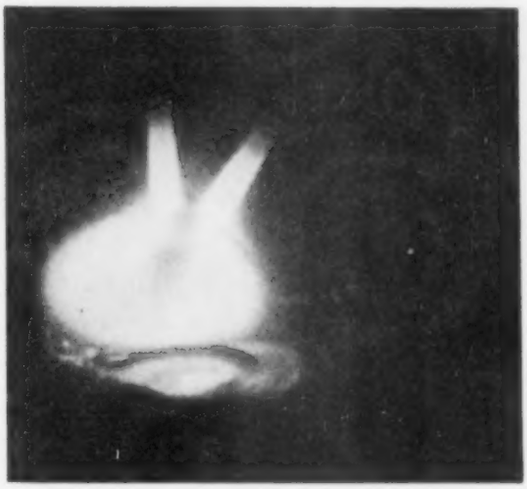


Fig. 2—An Atomic-Hydrogen Welding Arc

This unique welding process finds its greatest value and usefulness in the fabrication of new products, as well as in the repair of existing equipment where fusion welding is required on special ferrous alloys, such as chrome-, nickel-, and molybdenum-steels; non-ferrous metals and alloys, such as aluminum, duralumin, nickel, monel, copper, brass and bronze; welding thin sheet metals, including stainless steel, etc. Although it can be used for almost any fusion-welding work, atomic hydrogen is not quite so inexpensive as the ordinary arc-welding processes, and for that reason its usefulness is of maximum practical value on those applications which cannot be handled so successfully by ordinary methods.

Among the many examples of successful application of atomic-hydrogen arc welding, a large midwestern manufacturer employs the process to reduce cost and to overcome technical difficulties formerly experienced in the manufacture of heat-resisting tubing fabricated of a material which was "hot-short" and difficult to weld by ordinary means. The equipment paid for itself in the first year of operation and produced tubes free of oxidation and of much better quality. Scrap losses also were practically eliminated.

A western manufacturer, fabricating oil-well casings of hard red steel, found atomic hydrogen to be the only

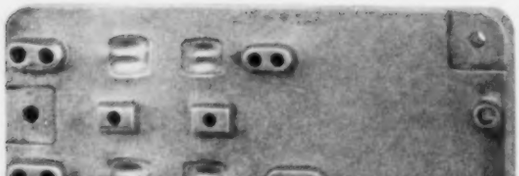


Fig. 3—A Worn Mold Plunger Before Reconditioning

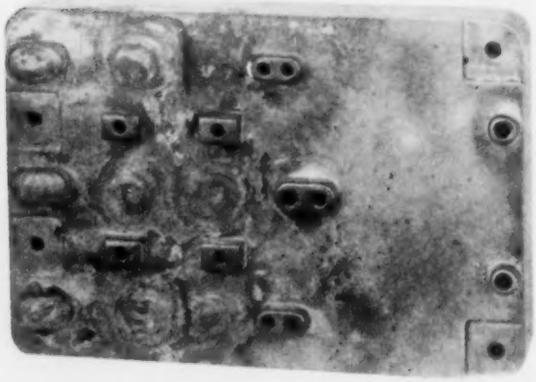


Fig. 4—Reconditioning Was Accomplished by Building Up Worn Spots by Atomic-Hydrogen Welding

Fig. 5—The Refinished Plunger After Welding and Remachining

means by which he could successfully get the unusually high ductility required.

Likewise, an eastern manufacturer uses atomic hydrogen extensively in the manufacture of motorcycle frames; others for welding stainless-steel tubing; others for welding monel metal; others for hard surfacing, etc.

HARD SURFACING

In the field of hard surfacing, atomic-hydrogen welding has proved to be an excellent means for applying Stoodite, Cristite, Borod, Blackor, tungsten carbide, etc., to the cutting edges of drills, cutters, bits and other tools, so that they can be used many times longer without being taken out of service for resharpening.

REPAIRING TOOLS, DIES, ETC.

In addition to the fabrication of new products, atomic-hydrogen arc welding is highly valuable in the repair of forming dies, forging dies, die-casting dies, permanent molds and similar equipment, as well as for alteration of existing dies to accommodate design changes or to rectify mistakes of machining. It is also used successfully in the repair of circular saws, high-grade machine tools, etc. Other welding processes have been used in this class of work but results have not been encouraging. Because of its outstanding performance, however, atomic-hydrogen arc-welding equipment is widely used in this class of repair work with eminent success, and has saved many thousands of dollars annually for users.

Fig. 6—A Die Block Saved by Atomic-Hydrogen Welding

Through error, a milling machine was made to cut below an arc scribed on the face of this die block made of oil-hardening steel. Fortunately, however, atomic-hydrogen welding equipment was available for use in salvaging both the material and labor which had been used. Although the quality of the deposit is A-1, the operator explained that he would have made a neater looking job had he known it was to be photographed.

Fig. 7—An Engineering Change Accomplished with the Aid of Atomic-Hydrogen Welding

Engineering changes frequently cost a great deal especially if they have to be made after work has progressed to a considerable extent as it had in the case of this die. Atomic-hydrogen welding was used and the needed metal (1/2 in. by 3/4 in. by 4 in.) easily and inexpensively added, to provide the same physical properties and chemical analysis as the parent metal. When machined, the surface was entirely free of pinholes, and when water-quenched it was of uniform hardness with no soft spots.

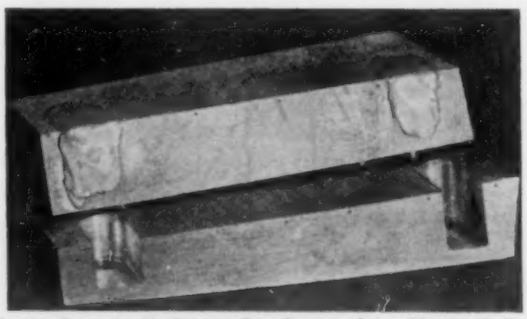


Fig. 8—An Error in Drilling a Die Corrected by Means of Atomic-Hydrogen Welding

Holes are often drilled or cut in the wrong places; this happened in making 20 of these die blocks.

Instead of having to scrap the blocks, the holes were partially filled by conventional arc welding, and the finishing passes were put in by atomic-hydrogen welding to avoid pinholes in the surface when finished and to provide a sound surface of uniform hardness when water-quenched.

ADVANTAGES OF PROCESS

The advantages of the atomic-hydrogen welding process over other welding processes for the types of work mentioned are:

1. Metal of the same analysis as the part being welded can be deposited. For this purpose the filler rod used in making the deposit should be of the same analysis as the part being welded, except that it should contain about one-third more carbon to compensate for the loss of this element. No appreciable change takes place in the other elements. Many manufacturers of alloys can furnish such filler rods. Ordinarily flux is not required.
2. The heat-treating properties of the deposited metal, therefore, are the same as those of the die or other parts, a feature which assures uniform composition for reworking and thoroughly reliable service from the repaired die. In fact, it is usually impossible to detect the repair after it has been machined and heat treated. In contrast, attempts to use hard-surfacing electrodes for die repair show that difficulties are encountered when it is necessary to anneal the die for reworking, as the deposit is not softened by the annealing temperature.
3. Atomic hydrogen produces an unusually smooth, ductile deposit free from any pinholes or impurities such as oxides and nitrides.
4. The weld is clean and free from scale and the work is not pitted by weld spatter. Undercutting is easily avoided.
5. The thickness of deposit can easily be varied from the thinnest surfacing to a heavy deposit. Feather edges can be built up without putting on excess metal. Definite savings are made by depositing exactly the amount of metal required, thus reducing machining costs.
6. Small sections of cutting edges can be built up without affecting adjacent areas by scaling, undercutting or spatter, so that reworking of the entire cutting edge can be avoided.

Dies, permanent molds and other special tools often cost hundreds or even thousands of dollars, and a welding process that will enable them to be repaired or changed is of correspondingly great value. Not uncommonly, the saving which the atomic-hydrogen process has effected in a single one of these jobs has paid the entire cost of the welding equipment.

APPLICATIONS

The following specific examples of successful applications of atomic-hydrogen welding indicate some of the many uses for this equipment. In addition, new uses are continually being developed where the welding has to be of a particularly high standard of quality, and where complex alloys are encountered.

Fig. 9—The Welding of This Fine Wire Mesh Shows a Successful Use of Atomic-Hydrogen Equipment and Illustrates the Precise Control of Heat Obtainable

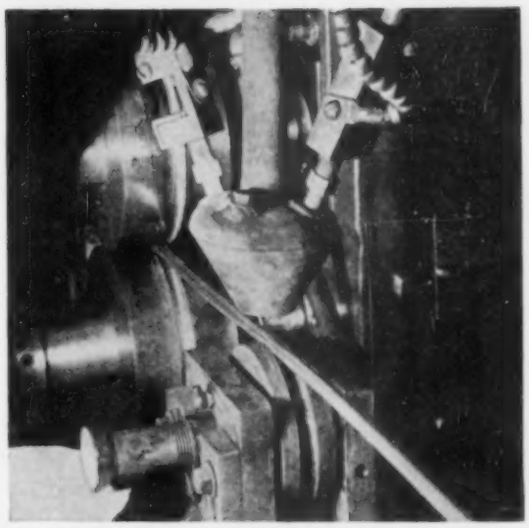


Fig. 10—Close-Up of Automatic Atomic-Hydrogen Arc-Welding Head Used to Fabricate a Special Heat-Resisting Alloy Tubing

Oil-, Water- and Air-Hardened Dies

Hardened dies, whether they are oil-hardened, water-hardened or air-hardened, can be readily welded by the atomic-hydrogen process. Filler rod of the same general analysis as the metal being welded should be selected, although it should contain the mentioned approximately one-third more carbon than is desired in the deposited metal. Best results will be obtained by having the hardened die annealed before welding. The annealed die should be heated to a cherry-red and the filler rod will flow in smoothly, insuring an absolutely sound weld with no pinholes or bubbles in the deposit. When welding sections of air-hardening steel, best results are obtained by keeping the die quite hot. Extra precautions should be taken, therefore, to prevent the die from cooling too much before the weld is completed. This is particularly important when large sections are involved. If the die tends to cool off too rapidly, the welding should be stopped until the die has been reheated to a cherry-red.

After the welding is completed, the die should be normalized and allowed to cool very slowly in powdered mica, lime or shredded asbestos.

Composite Dies

Large dies have been successfully built with the aid of atomic-hydrogen arc-welding equipment by employing composite construction. In this type of work, the body of the die is usually made of a good grade of cast steel, while the cutting edges, forming edges, or other portions subject to extreme pressures are built up from the desired quality of tool steel. Substantial savings have been effected by such construction.

Changes and Corrections in Dies

Many times, after a die is in the process of being machined, last-minute engineering changes may require an alteration in the shape. If the change involves removal of more metal, the problem is relatively simple. However, if the change involves the addition of metal it may mean scrapping all the work which has been done and starting over, unless atomic-hydrogen welding equipment is available to use in properly adding the needed metal.

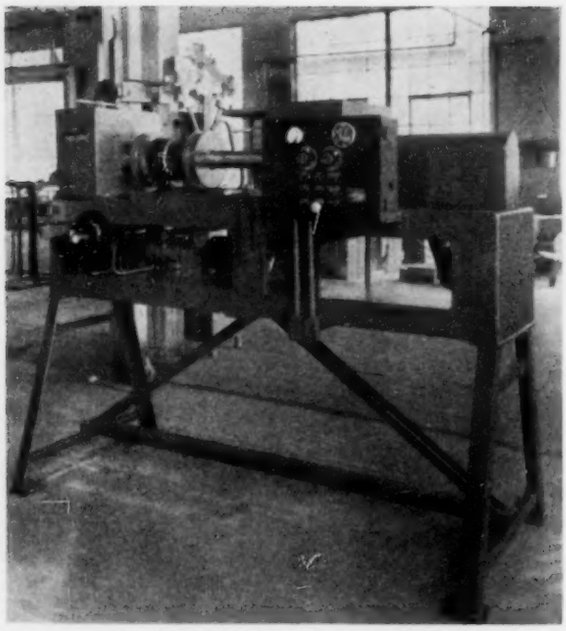


Fig. 11—An Automatic Atomic-Hydrogen Arc-Welding Machine Used to Weld the Spheres Shown in Fig. 12

Again, it is often found that a minor change in design of the particular part being produced needs to be made after the die has been in use for a short time. Although it may be in good shape otherwise, such a die often may have to be scrapped or rebuilt to incorporate the desired changes, unless atomic-hydrogen welding equipment is available.

Likewise, errors in machining can be readily corrected by atomic-hydrogen welding with the assurance that the welded part is just as satisfactory in every respect as a completely new piece.

Die-Casting Dies

Die-casting dies that have been in service for some time may become marred or scratched when the operator uses an ejecting tool in removing the casting. Such dies are unsuitable for further use because most die castings receive very little finishing and any slight imperfection in the die will show up in the finished product. On this type of repair work it is possible to add just a spot of molten metal to the marred section, and to work it out to a smooth feather edge by playing the atomic-hydrogen flame over the deposited metal, leaving very little excess for the toolmaker to machine away. The absence of spatter or scale on the finished part of the die adjacent to the weld is of further advantage in work of this kind.

Permanent Molds

The welding of permanent molds is another large field of application. Such molds vary widely in purpose and size, many being quite costly because of the intricate machine work required to get the patterns desired. Some of their principal uses include the molding of plastic materials and rubber compounds. Usually, the surface must take a mirror-like polish. One outstanding example of this type of mold is that used in the manufacture of automobile tires. Many times there are minor changes required in the contour, such as in the tread design or even in the lettering on the mold, which can be readily filled up and recut to save the entire mold.

Forging Hammers

The sow-blocks and rams of large forging hammers are usually made of hard alloy steel. As a result of the terrific blows these pieces receive, progressive failure takes place because of fatigue, and frequently a section of the metal will break away. The weight of such sow-blocks and rams sometimes runs as high as 4000 to 10,000 lb. and, naturally, replacement is a very costly matter. The use of atomic-hydrogen welding equipment for repair often avoids such costly replacements, because it is possible to obtain a filler rod of the correct analysis and rebuild the section which has been broken away. In this way, all of the physical and chemical properties of the parent metal are retained in the repaired section. Attempts to make such repairs with other welding processes have never been very encouraging because of the difficulty ordinarily encountered in handling an alloy rod and in making a proper deposit. Experience shows that the atomic-hydrogen process is the only one known to produce the uniform, close-grain structure required.

USEFULNESS IN TOOLMAKING

Toolmakers who are familiar with the advantages of atomic-hydrogen welding demand that their work be done by this process in order to obtain a weld free from pinholes, undercutting, spatter, etc., and in order to obtain deposited weld metal which will be uniformly hard after heat treatment. The amount of machining necessary after a die has been repaired is very small compared to that which is necessary when attempts are made to use other processes, because with the latter a bead of appreciable thickness is necessary to get any kind of a deposit. Furthermore, in most cases it is almost impossible to obtain a welding rod which can be used with the ordinary arc-welding process to produce a deoxidizing vapor around the arc, to prevent the formation of oxides and nitrides, and to eliminate the coarse structure which results when alloy rods are not protected by a proper coating. With gas welding, it is very difficult to control or to prevent a decided burnout of the carbon in the filler rod, while it is being deposited. This lack of transfer of carbon causes soft spots in the die, depending on the amount of carbon lost, with the result that the die soon wears or deforms under pressure, thus causing imperfections in the product. This, of course, necessitates scrapping the die.

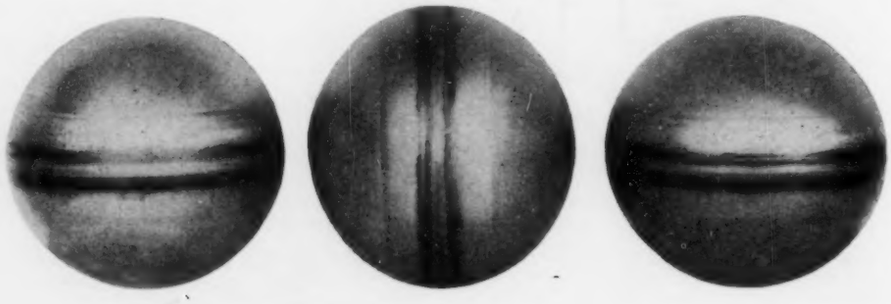


Fig. 12—Spheres 2½ to 10 In. in Diameter Are So Welded by the Machine Shown in Fig. 11 That But a Slight Ripple May Be Felt in Their Surfaces

MATERIALS THAT MAY BE WELDED

Carbon Steels.—Carbon steels with a carbon content as high as 1.25 per cent have been successfully welded with the atomic-hydrogen process.

Chrome Steel.—Chrome steels having a chromium content up to 40 per cent have been successfully welded with this process. The resultant welds are not particularly brittle if the chromium content is less than 20 per cent and usually will not require heat treating. Ascoloy, which has a chromium content between 12 and 16 per cent, is included in this class of steel. If the chrome content is over 20 per cent, heat treatment after welding will relieve any tendency toward brittleness.

Special Alloys.—Modifications of chrome steel, particularly by the addition of nickel, have resulted in stainless steels such as KA-2, Enduro, Allegheny Metal and Super-ascoloy. This addition of nickel aids in welding and makes possible the production of strong ductile welds without the necessity of subsequent heat treatment —that is, as far as the weld itself is concerned. However, it is necessary to heat treat after welding if restoration of full stainless properties is desired.

Non-Ferrous Alloys.—Most non-ferrous alloys can be welded successfully by the atomic-hydrogen process. Calorite, a 15 to 20 per cent chromium, 80 to 85 per cent nickel alloy, can be welded, not only in a worked form, but also in the form of a casting. This metal is used for resistance units and heaters for electric furnaces, in which the welds are subjected to severe strains which they readily withstand.

A more common non-ferrous alloy is brass. As a general rule, alloys of copper and zinc are difficult to weld because of the lower melting point of the zinc. The result, therefore, in welding this metal is that the zinc has a tendency to vaporize before the copper has reached its melting point. When the brass contains more than 40 per cent zinc, welding is practically impossible. For brass with a zinc content of less than 40 per cent, a flux is needed in welding with the atomic-hydrogen process.

The process has also been used successfully in welding monel metal, such as that used in gasoline-storage tanks and other applications.

TECHNIQUE OF ATOMIC-HYDROGEN WELDING

The technique of welding by any process is primarily a matter of craftsmanship. The proper technique in getting best results with atomic hydrogen is no more difficult or involved than with any other welding process. Its acquisition rests ultimately with the individual. With a few hours of practice, an operator can learn how to start the equipment and to make the proper adjustment of welding current and hydrogen flow. With this knowledge and a few simple rules, he can make satisfactory welds on plate stock. Skill in the welding of complex sections, the repair of molds and dies, and similar work, must be acquired by experience or under the direction of a competent instructor.

Familiarity with other methods of welding is of some assistance to the operator who is just learning to weld with the atomic-hydrogen process. To a considerable extent, the manipulation of the atomic-hydrogen torch is similar to welding with a gas torch. Steadiness of hand and accuracy of touch are required for best results. General knowledge of counteracting warpage is also helpful.

Since the arc is established between two electrodes, the work does not form a part of the electrical circuit and, therefore, does not need to be grounded. A filler rod may or may not be used, depending on whether the desired joint requires the addition of metal. The tungsten electrodes do not enter into the weld, although they are very slowly evaporated by the intense heat of the arc.

The arc stream has a very definite circular outline, with the greatest concentration of atomic hydrogen (and therefore heat) at the boundary of the arc stream, the edge of which should just touch the surface to be welded. The amount of heat available for welding depends on both the welding current and the size of the arc fan.

With these features for guidance, supplemented by actual experience with the atomic-hydrogen welding arc, the operator will readily acquire the technique of producing unusually smooth, uniform, strong and ductile welds either manually or by an automatic welding machine equipped to use the atomic-hydrogen process.

Discussion of S. T. Smetter's Paper on Shrinking of Steel*

By C. R. WHITTEMORE, M.Sc.†

IN commenting on Mr. Smetter's paper on the "Shrinking of Steel" the writer wishes to draw attention to a few of the statements which may lead one to adopt expensive and unsatisfactory methods in overcoming or at least minimize distortion due to welding.

In the first place the control of distortion must be based upon a knowledge of the behavior of the metal under the stresses introduced by the welding process and the effect of temperature upon the metals being welded.

First, let us consider a ball and a ring made of nickel, the ball when at room temperature just neatly passing through the ring. Heat the ball to 400–500° F., keeping the ring at room temperature, and it will not pass through the ring. Now cool to room temperature and it will readily pass through the ring. If a cast-iron ball be used and heated to 400–500° F. the same results would be obtained but if heated to 1200° F. and held at temperature for an hour or so, then cooled, it would not pass through the ring owing to an increase in volume through structural changes of the iron.

The theoretical curve of expansion and contraction is a straight line indicating that during heating and cooling the rate of expansion is directly proportional to the temperature. In general, steels heated below their transformation or critical points follow a straight line but when heated above the critical points the periods of absorption and evolution of heat are accompanied by definite changes in volume of steel being heated and cooled.

For certain alloy steel expansion is not quite proportional to temperature for at higher temperatures expansion is at a greater rate than at very low temperatures.

The most important factors contributing to distortion in a welded structure are: (1) welding technique, (2) procedure and sequence of welding, (3) accuracy of fit-up, (4) design of structure, (5) materials employed.

Welding Technique: European practice is to use small

* Paper presented at Annual Meeting, A.W.S. and published in October 1939 WELDING JOURNAL.
† Deloro, Ontario.

electrodes with low welding currents, while American practice prefers large electrodes and high welding currents. The former claim that their technique produces less distortion and lower residual stress than the latter technique. The following results from extensive tests made by McGill University (Ref. JOURNAL OF THE AMERICAN WELDING SOCIETY, Dec. 1934) and others do not substantiate the claims of the advocates for small electrodes.

Weld	Stress in weld
Bare electrode, one pass	12,000 lb. per sq. in.
Bare electrode, two passes	19,000 " " " "
Covered electrode, one pass	27,000 " " " "
Covered electrode, two passes	37,000 " " " "

In the Union Melt welding process, where plate thicknesses from 1/4 inch to 2 inches in thickness can be welded in a single pass the distortion is approximately 50 per cent less than with hand welding in multiple layers. This is due to the weld being made in a single pass which produces a more uniform distribution throughout the cross section of the joint. In the welding of rigid or heavy structures the uniform preheating, particularly in cold weather, and holding at temperature during welding followed by slow cooling afterwards materially lessens the stresses in the welds. Also the stress-relieving at 1200° F. of heavy plates before assembling into the structure materially lessens the stresses and distortion in the completed structure.

Procedure: The close fit-up of parts to be welded is of paramount importance in the welding of heavy material and to a lesser degree with light work. The procedure in fabricating by welding in the case of light work is to tack-weld the parts together and proceed with the welding having the work clamped rigidly. Sequence of welding must be planned in order to have the least distortion, e.g., by back-stepping, by welding on alternate sides of the joint, by light peaning, by keeping the weld size to requirements. With heavy plate work the parts should be assembled so that they are free to move without going out of alignment.

Joint Design: The design of the joint should be such that the cross-sectional area of the weld for a given thickness of plate is a minimum. Distortion is greatest in V-welds, next in U- and least in double V- or U-welds.

Materials: The joining of plates of different thicknesses places more distortion in the thinner plate since the amount of heat put into a weld is governed by the heavier plate. The analyses of the weld metal and the parent metal are not the same and the weld metal from different electrodes produces varying amounts of distortion. Also the stresses due to rolling of the plate or shape are quite variable and are more often a greater factor in producing distortion than differences in metal composition. Localized heating and cooling of a welded structure release these rolling stresses as well as the welding stresses resulting in increased distortion but spread over a greater area.

The heating and cooling of a welded structure by increments place a great deal of locked-up stress, through shrinkage, in the structure. By the use of the correct sequence of welding, the welding in units which are assembled into the whole structure and the welding of these units in the proper order, no serious distortion will occur. By checking the work for distortion during welding its occurrence is discovered and corrected before it becomes serious. The examples, "Head Gates" and "Machine Girders," straightened by heating and cooling are typical of the class of structural welding which lends itself to sub-assembly and sequence welding, to keep distortion within allowable limits. Such examples as these emphasize the need for qualified supervision and inspection during progress if welded fabrication is to progress and show the economies that it is capable of effecting.

DESIGN OF WELDED RIGID FRAMES

By MARTIN P. KORN*

MY FIRST paper on this subject published in THE WELDING JOURNAL in June 1939 brought forth questions many of which are of general interest. This paper prepared in advance has been revised to include their discussion.

BASES FOR WELDED RIGID FRAMES

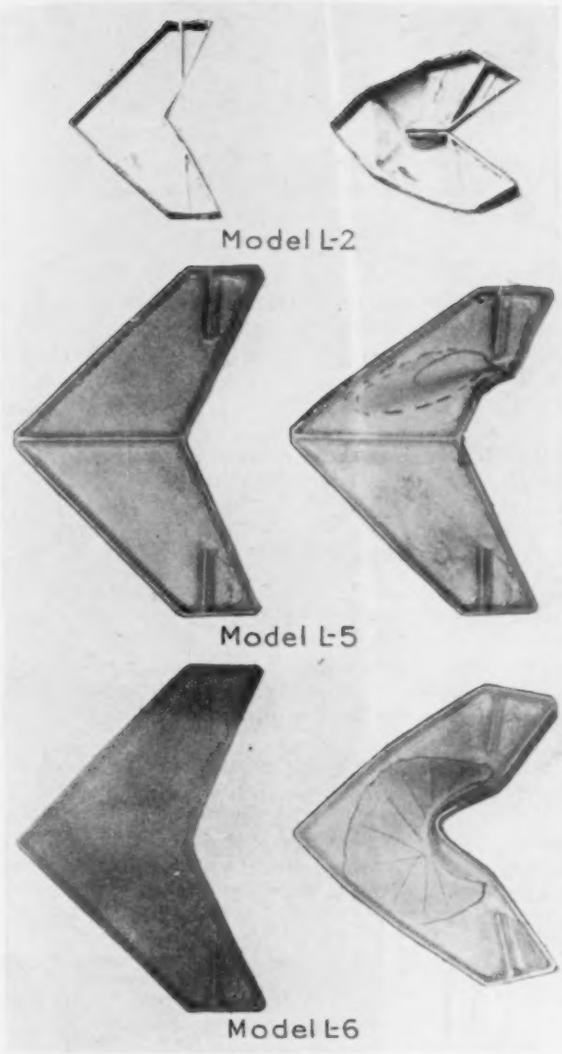
The question of whether to use fixed or hinged bases depends entirely upon the specific problem and the designer. We can evaluate the effect of all types of bases on the stresses in frames. But it is important that we first agree on what we mean by fixed or partially fixed bases. For it is a fact that some designers do not fully realize that their fixed bases remain fixed only in their design notebooks.

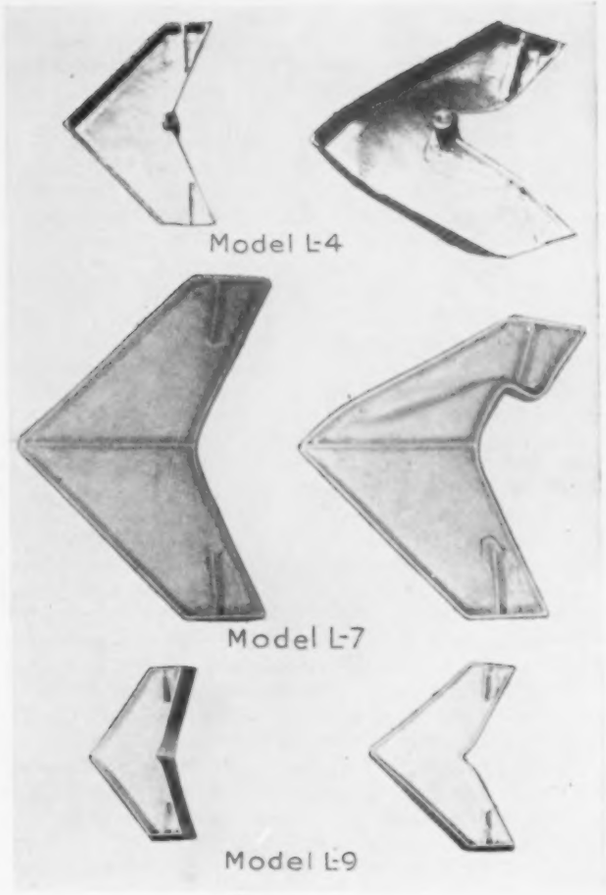
Strictly speaking, no base of a structure can be considered as fixed except one in rock or hardpan. Steel piles frequently settle under loading, likewise all types of spread footings. Even in subways at great depths, settlement occurs where you would not ordinarily expect it.

* Consulting Engineer, Buffalo, N. Y.

Because settlement may occur, it is to be expected that some rotation of the bases will follow, since neither maximum nor minimum loading conditions will produce equal distribution of soil-bearing pressures on the base. If, therefore, you design rigid frames with fixed bases not bearing in rock, you have no assurance that your structure will be fixed. You can more safely assume that it will not be fixed. The restraining moment acting on the base will be something less than the moment necessary to completely fix the base.

The only result you can really be sure of when you design for fixed bases is that your rigid steel frame and bases will act together toward absorption of the stresses due to the loadings. In other words, you change the behavior of the steel frame when you unite it with the footings. You change, likewise, the behavior of the footings. Briefly you make your foundation an integral part of the steel frame (independent of the soil), the stresses in the structure depending entirely upon the extent and manner of its union with your foundation. Fixed bases serve somewhat in the manner of laced shoes on a man's body, the higher and stronger the lacing, the greater they function jointly with the body movements and stresses.





Tested Steel Knees

In a steel rigid frame having hinged bases, the footings serve only as "soil-bearing plates" just as wall plates for wall-bearing beams.

It is plain then that whether you design the rigid frames for fixed or hinged bases, the behavior of the structure is elastic throughout unless it rests in rock.

In the light of this fact we can set down as axiomatic that fixed bases affect only the stresses in the rigid frame —they do not determine the fixation of the rigid frame. There lies a difference which it is important to understand in the calculation of stresses. Realization of the fact that rotation does occur in fixed bases, even though slight, will make a difference in your design.

Comparing briefly the results of a design with fixed bases to one having hinged bases, the stresses in the columns vary the greatest, the stresses in the knees in a lesser degree, the stresses in the deck or roof beams in a still smaller amount, not enough to change your design should you change the type of bases. This applies only to symmetrical loadings.

TIES BETWEEN BASES

The question was asked, "Are ties necessary for safety?" Most rigid frames can be designed with safety without ties. Under some conditions it may be more economical to provide ties and reduce the material required in the rigid frame proper.

If you design for fixed bases, ties will generally not be required. If you design for hinged bases, ties will be necessary unless you design the rigid frame and bases to take the horizontal thrust. Ties according to their design will take a certain proportion of this horizontal thrust; the remaining portion will be distributed to the rigid frame, the bases and the backfill (if present) in proportion to their relative ability to take horizontal forces.

For a deck bridge with backfill against the legs of the frame, you can usually with safety use hinged bases without ties. For an ordinary mill building frame, ties are usually objectionable because of floor trenches, machinery foundations, etc. In that case it is better to design without ties.

Prestressing the ties by some methods produces bending moments in the rigid frame, some of which will be in the same direction as moments produced by loads on the frame. A careful study of the problem is necessary before it can be determined whether anything can be gained by prestressing the ties.

LOCATION OF NEUTRAL AXIS

Information was requested proving statement in my June 1939 article that the center of gravity and the neutral axis in knees do not coincide.

According to our present accepted theory of strains and stresses in elastic materials, the strains from bending are proportional to their distance out from the neutral axis in beams with straight axes.

In beams with curved axes, such is not the case. The

fiber lengths between radial sections vary in length and if plane sections remain plane after bending, the unit strains are not proportional to their distance out from the axis. Any standard text-book on strength of materials will explain that point.

In both cases of straight and curved axes, bending will produce a rotation of all cross-sectional planes normal to the axis. This rotation is caused by the tension and compression stresses acting on the fibers between two adjacent cross-sectional planes normal to the axis.

If we are to have flexure in the knees, and they are composed of the same elastic material and subjected to bending moment as the rest of the structure, then the neutral axis must assume a position such that cross-sectional planes normal to the elastic axis will not overlap and will be at least an infinitesimal distance apart at any point.

This is a physical or boundary condition which will cause the elastic axis to deviate from the center of gravity of the section within the range of influence of this boundary condition. In order to have cross-sectional planes normal to the axis which do not intersect within the section, the neutral axis must be curved and of a radius greater than the distance from the neutral axis to the boundary of the material.

The location of the neutral axis, then is dependent on the radius which it assumes and the laws of equilibrium between the internal stresses and the external forces together with the principle of conservation of energy. Since the elastic axis becomes curved to a relatively small radius within the knees, radial stresses necessarily increase in importance and must be investigated. The function and importance of these radial stresses will be shown in the discussion to follow herewith.

Analysis of knees by polarized light by recognized experimental laboratories together with tests of models of knees of different materials conducted by the writer substantiates the above theory of action within the knee. This analysis will be treated separately in a later article.

WELDED VERSUS RIVETED JOINTS

A prominent bridge engineer asks:

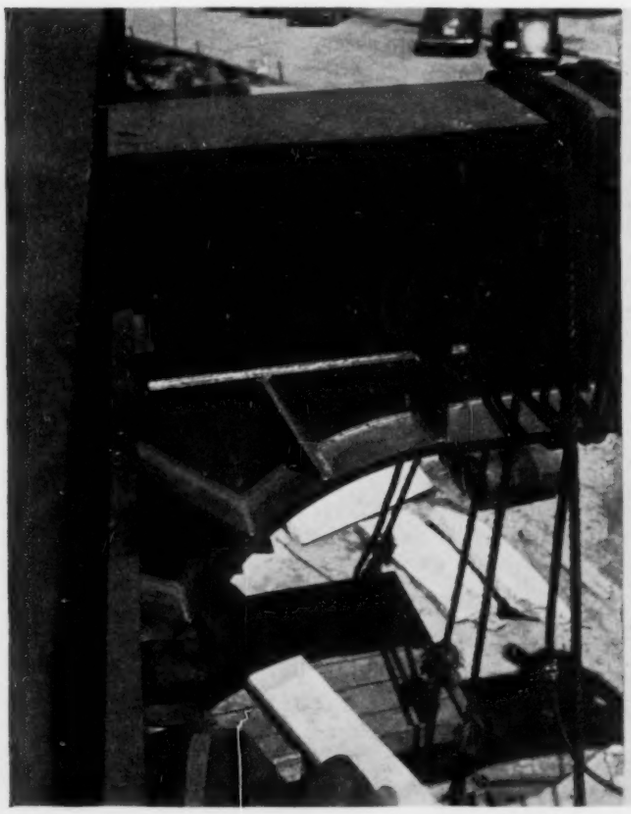
1. Can you design a welded joint as accurately and depend on it as you do on a riveted joint?
2. How about eccentric welded joints compared with eccentric riveted joints?

It is to that class of highly responsible engineers to whom this series of articles is primarily directed. Engineers who labor those questions are respectfully referred to the *A. S. C. E. Proceedings* for May 1939, article entitled "Tests of Riveted Joints" by Davis, Woodruff and Davis, and to other articles on that subject through 1938 and 1939, including one by T. H. Rust in the November 1938 *Proceedings*. Then follow through with the discussions.

Let us quote some excerpts at random from the discussions of the riveted joints:

C. F. Goodrich, Chief Engineer, American Bridge Co., "The authors have arrived at some startling conclusions one of which has been suspected by some engineers, namely, that designers have been wasting effort trying to maintain an optimum net section at the ends of connections of splices by the use of considerably fewer rivets in the end rows."

Frederick P. Shearwood, Consulting Engineer, Dominion Bridge Co., "The distribution of the loads in the rivets and the stresses in the material of large riveted joints is one of the problems that, on account of its complexity and the many indeterminate factors which enter into its resistance, have been avoided by mathematical theorists: and these joints have been designed



Photos courtesy Lincoln Electric Co.

Main Ave. Bridge, Cleveland, Ohio

by simple empirical rules and the designer's common sense and judgment."

Jonathan Jones, Chief Engineer, Fabricated Steel Construction, Bethlehem Steel Co., "Most if not all of the tension members in riveted bridge trusses now standing have been detailed on a certain assumption which the experiments tend decidedly to disprove."

In deference to the above authorities and the subject you are asked to read their full discussions. That will tell you quite definitely how riveted joints have been designed all through the years. Consider also that all designs were based on results learned from old tests. To quote *Engineering News-Record* of Feb. 16, 1939, "Specifications commonly employed in the design of structural riveted connections are based largely on tests made at Cornell University in 1904, on joints of relatively small size having a maximum of nine rivets in either end and made of softer plate and rivet steel than now used."

All questions pertaining to the design and strength of welded joints must be approached from the point of view that if the designer has a mental awareness of the internal stress action of his joints, he can in most cases design a welded joint superior and more economical than a riveted connection. Welded joints can be made more effective in the transfer of stress. Discontinuities in sections may be avoided which will reduce stress concentrations. Welds can be placed at points of maximum advantage. Gross sections can apply.

Erroneous conclusions have been reached by some who observed the action of joints in which welding was merely substituted for rivets. Welding has inherent characteristics which must be used to secure its maximum benefit. Welded joints well thought out by a designer mentally aware of his structure's action can be as near the attainment of ideal joints as practical and economic considerations will allow.

Most helpful toward a better understanding of the strength of welded joints would be your observation of a test to destruction of a welded structural assembly or even welded joints. The welded joints alive and unbroken beside the ruptured parent material would definitely eliminate all doubts and erroneous impressions about welding. And those joints are perforce the criteria upon which welded design is based and upon which welding specifications are based. This is something the designer should consider when he would compare welded with riveted joints.

KNEES

Functioning of Knees in Rigid Frames

Stresses within rigid frames must turn the corners at the knees. In order that a force change its direction, it must be acted upon by another force or forces with a transverse direction. These transverse forces occur within knees in the form of radial stresses. The radial stresses combine with the circumferential stresses and curve the paths of stress around the knee.

The tension area of resistance sprawls out over most of the knee. The compression area of resistance has so much smaller space in which to perform even more work. In consequence, the compression stresses become much greater than the tension stresses. Two different behavior patterns thus exist unlike each other and both different from the normal.

An analysis of the stresses in a knee involves, therefore, the analysis of two individual parts. And if you consider them as separate bodies according each individual treatment, they will not be difficult to understand.

If the knees be weak, it might mean failure to your structure. For the roof or deck beams can be overstressed even beyond the elastic limit and the structure will stand up as long as the knees and the columns are adequate. The knee should therefore dominate the frame. It must be of sufficient size and strength to act as bumper and traffic center to rout all stresses around the frame. It must also be flexible so that it can bend and redistribute stresses due to abnormal loadings around the frame. In other words, it must have strength and flexibility of greater magnitude than the combined efforts of the forces in the roof beams and columns.

If the rigid frame be overloaded or its legs give ground to the earth, the knees will feel the strains first. Designed to dominate, they will at once make the roof beams and the columns extend themselves to cover an emergency. And in many cases the roof beams and columns can take up to 50% more stress than ordered in the design computations and return to normal after an emergency. We see then how unusually safe your rigid frame can be if only you give the knee which constitutes so small a part of a rigid frame the upper hand.

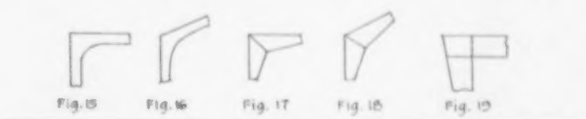
A good design for a rigid frame should, therefore, set up a life line around the knees. This is not to imply loading down the knee with excess steel and excess welding, which might do more harm than good.

We shall now proceed with a study of a knee as in Fig. 15. We shall study separately its tension area of resistance and its compression area of resistance by cutting the knee along its neutral axis as in Figs. 15A, 15B, and 15C. The diagrams shown have been drawn out of proportion solely for illustrative purposes.

BEHAVIOR CHARACTERISTICS OF TENSION RESISTANCE AREA

Let us concentrate on Fig. 15*A* as though it were an individual member.

If certain forces were applied to this member so that its stresses became exactly like its prototype in the knee



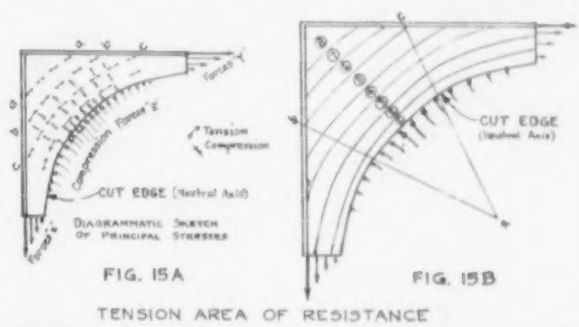


FIG. 15A

FIG. 15B

TENSION AREA OF RESISTANCE

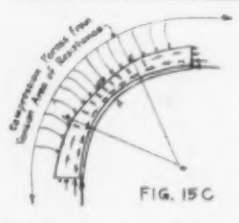


FIG. 15C

COMPRESSION AREA OF RESISTANCE

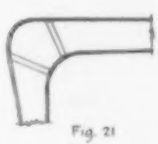


Fig. 21

Fig. 20

proper, those forces would appear as in Fig. 15*A*. The external forces *x* and *y* at ends of member would make for tension in the member. The external forces *z* along the cut edge (neutral axis of knee) would induce radial compression stresses in the member. The tension strains would be maximum at the flanges, diminishing to zero at the cut edge.

On Fig. 15*A* have been shown the paths of stress. We know that the strains will cut the outer corner and pass through the web. It is obvious even to inspection that somewhere along plane *b-b*, there would occur the maximum tension. It is also obvious that along the path of stress, the compression normal to the path will be diminishing from its maximum value which occurs somewhere near the cut edge (neutral axis of knee).

If you were to design a structural member acted on by forces indicated in Fig. 15*A*, you would probably provide one or more web stiffeners or make web thick enough to resist buckling without stiffeners. The simple picture you see of the stress behavior in this member is that exactly of its prototype in the full knee.

Let us now examine Fig. 15*B*, another view of member 15*A*. Imagine, if you can, that each fiber within this member stood out to the naked eye in the manner in which it is stressed. Such a picture cannot be illustrated, so that for the purpose only of illustration we shall assume that the member had only eight fibers as shown.

Fiber 1 would obviously get little or no tension but it would get a high radial compression. Fiber 3 would have far more tension but less radial compression. You will observe that fiber 3 continues down into the web, above it fiber 4 into the flanges. Fibers 5 to 7 similarly run into the flanges. The maximum flange stress consequently occurs between fibers 4 and 7. (Actually it occurs only in one of those fibers.)

It must be remembered that these fibers do not represent constant unit stresses around the member (or its prototype in knee). They are illustrated graphically to assist the reader to visualize just how the material must work to carry the stresses around a curve.

Let us see if we can pick up similar points of maximum flange stress in some of the tested models. Note the bend points in the flanges in models *L*-2 and *L*-4. In radial planes along those bend points on these models occurs the maximum tension corresponding to that in fibers 4 to 7 in Fig. 15*B*.

The compression at any point along the cut edge (or neutral axis) equals the summation of the radial compression stresses in all fibers in radial plane through that point.

If for Fig. 15*B* you visualized myriads of thin stranded wires replacing the eight steel fibers, those wires stayed laterally, you could imagine the wires bearing the maximum tension strains bearing down and rolling over one another. They would of course be restrained in the flanges, in other words, find "anchorage" in flanges around points *b* and *c*. Some designers through a good sense of stress behavior intuitively place stiffeners along planes *ab* and *ac*, those stiffeners serving as "anchoring posts." Others use plates there to stiffen web as shown in Fig. 21.

With the maximum tension in the stranded wires obtaining between points *b* and *c*, and with stress in each wire decreasing down toward the cut edge, can you now further imagine a condition where around center of cut edge, you might possibly have "slack wires?" By slack wires I mean only loose wires without anchorage subject only to compression. Such a condition actually occurs creating areas possessing no tension strains above the neutral axis in a knee.

An effort has been made to focus attention to the critical points of stress through an abbreviated illustration of the stress behavior. Knowing where the critical points of stress occur in any member is what makes for good design. It also insures safety to your structure. If your computed stresses deviated 10% or even 20% from the true stresses based on the critical points of stress, they would make for a better and safer design than mere mathematical analyses of an inanimate body varying 5% from some hypothetical assumption.

If you understand the above illustrations, you will understand the knee's behavior above the neutral axis.

BEHAVIOR CHARACTERISTICS OF COMPRESSION RESISTANCE AREA

Figure 15*C* represents only the compression area of resistance cut from the knee Fig. 15 along its neutral axis. Let us now concentrate on Fig. 15*C* as though it were an individual member.

If certain forces were applied to this new member so that its stresses became exactly like its prototype in the knee proper, those forces would appear in magnitude and direction as illustrated in Fig. 15*C*. The maximum stress would occur along the flange and it would decrease toward the cut edge or neutral axis.

It is plain that the maximum compression would occur in area *ed* and that it would extend in all directions in plane of member. Area *ed* therefore is the critical stress area in this member bearing concentrated stress. The intensity of concentration decreases with the increase in radius of the flange.

At the ends of this member only one-way compression occurs. Those ends get no compression from the tension resistance area.

Test model *L*-6 having no stiffener shows the failure effect of the stress concentrations. Test model *L*-7 with stiffener indicates the strengthening effect of the stiffener.

For the purpose of determining the value and effect of stiffeners, test model *L*-9 was designed with thick web and thinner flanges, the section having the same moment of inertia as section in Model *L*-5. It took more steel and had less strength than *L*-5.

Leaving the matter of stiffeners for a moment, consider what you would do if you had to design a member as in Fig. 15*C*. The entire member is in compression. You would investigate and design it without trouble. Actually the picture is that of its prototype in a knee.

You would quickly use web stiffeners between planes *ab* and *ac* or design web for its critical stress without stiffeners. You would automatically investigate unsupported width of flange in case you used no stiffeners and thicken it if necessary.

Should you design web without stiffeners, about five-eights of the web metal would be excessive in weight. When you stop to consider that the tension strains are much less than the compression strains in a knee and that the tension area of resistance is more extensive than the compression area, you will realize at once your waste in web metal when you design the large web for the small critical area of concentrated stress. In a design of magnitude, it runs up the tonnage.

DESIGN OF KNEES IN WELDED RIGID FRAMES

The above condensed notes on knee behavior focused attention only to the critical points of stress with which you are mainly concerned for practical design. A knee as in Fig. 15 was cut along its neutral axis after the knee had been subjected to stress. Forces were substituted on

the individual members that would result in the same strains in their prototypes in the knee proper. Observations were then taken on these separated bodies illustrated in Figs. 15*A*, 15*B* and 15*C*. Combining these observations should give us a picture of the stress behavior in a complete knee. Let us summarize them in terms of fundamentals essential to good knee design.

The maximum compression strains are much higher than the maximum tension strains. And they have much less living space than the tension strains in which to perform even more work. The compression area of resistance must therefore be more heavily armored.

The web around the center of the compression flange is stressed in all directions. That invites both buckling and crushing (see tested model *L*-6). Thickening the web here is one solution. But thickening a plate does not make it as good and economical a strut as a tee. Stiffeners in this highly compressed area make for greater strength and economy. They make tees of the web. Model *L*-7 with stiffener proved 60% stronger than model *L*-6, within the elastic limit.

This highly compressed area likewise makes for buckling in compression flange. The flange can be thickened here. But web stiffeners, too, will effectively strengthen the flange. Web stiffeners will consequently serve both the web and the flange of the compression area for strength and economy. They should be welded to the compression flange.

In the tension area of resistance the web can buckle from the radial stresses that cause compression. Web stiffeners will offset that. They need not be welded to the tension flanges unless flanges be very wide.

In brief, a good design would "heavy up" on the compression area with greatest resistance in all directions around center of compression flange. The tension area of resistance would be lighter. Your knee would then possess both strength and flexibility—all potentialities to dominate the frame. Dominance implies the ability of knee to disperse into its contiguous members excess stresses caused by extraneous forces. Such stresses might result from uneven settlement, from side sway not assumed in design, from other causes. Effective toward insuring such dominance are web stiffeners. They make for an increase of from 20 to 60% in strength of knee throughout its critical area by tapping the concentrations and redistributing the stresses when the web material reaches the stage near buckling. Where more than two pairs of stiffeners are used in knee, it is believed that short stiffeners above the compression flange would suffice to strengthen the heavily stressed concentration area.

A good example of knees embodying the above design principles is shown in photographs herewith of the new Main Avenue Bridge at Cleveland, designed in office of Cuyahoga County Engineer John O. McWilliams, Mr. W. E. Blaser, County Bridge Engineer, Mr. Fred L. Plummer Chief Design Engineer. Note the compression area of resistance much heavier in the web than the tension area of resistance. Note the shorter stiffeners to reinforce this compression area. Plainly the designers gave consideration to the stress behavior in the knees. This structure marks a new step forward for better design of welded rigid frames even though you might question the large number of stiffeners used.

At the beginning of this paper, Figs. 15 to 19 were mentioned as being typical of most knees. The behavior pattern in Fig. 15 varies in the other types only to the extent that you either relieve or intensify the concentrations.

Figure 16 develops lesser concentration of compression stress than Fig. 15, and the least of the types illustrated.

A knee as in Fig. 17 with sharp inner corner will develop high stress concentrations and must have stiffeners there (see models *L*-2 and *L*-5).

A knee as in Fig. 18 with stiffeners makes for strength and economy throughout frame.

In type shown in Fig. 19, the highest stresses occur at the inner corner. Beyond this critical point, the flange and web stresses diminish rapidly. Where a knee of this type is used, it would not be economical to design buckle or beam for this critical flange stress. Reinforcing the critical areas of the flanges and the web would be least costly. In this type of knee, web would tend to buckle as in Fig. 20 in a diagonal plane. The outside flanges alone counteract that. The compression flanges just beyond the inner sharp corner (point of restraint) also tend to buckle due to unsupported width. The question asked, "Why can't you just cut off the corner since it bears no stress?" can now be answered. If you cut off that corner, you lose the web stiffening values that the continuous outside flange provides. Rounding off the corner will not decrease strength of knee but the flange should be continuous.

Let us now look at Fig. 21, illustrating a knee that has been used in some designs. The web reinforcing plates placed about as shown are effective for redistribution of stresses throughout the knee. If you look back at Figs. 15*B* and 15*C*, you will observe that those plates follow closely planes *ab* and *ac* which for lack of other expression I have termed anchorage planes for the maximum tension strains. Use of such plates indicates that consideration has been given to the stress behavior in knees. But they are less effective than stiffeners. Neither do they serve toward dominance and flexibility in the knees as the metal in the Cleveland Bridge mentioned herewith.

In rigid frames for buildings, struts should be provided between bents at knees and at ridges. Eave struts should not be considered as replacing knee struts between bents. Stiffeners may be omitted in knees if ends of struts are designed to replace them.

Wherever rigid frame bents are closely spaced and restrained by concrete as in bridges, underpasses or subways, the concrete and steel can safely be designed as a composite unit. Experience proves that you may safely increase the unit stresses in the steel 20% provided the design follows the structural behavior pattern. For knees in this type of composite design, short reinforcing bars placed in concrete in corner knees and straight reinforcing bars in concrete at level of top flange of multiple spans combine to make the strongest and most economical type of structural welded frame.

A few words in conclusion on some questions pertaining to design procedure:

When you start the design of a rigid frame with an assumption (no one can do otherwise) and you end up only with a mathematical conclusion, what performance can you legally expect of a rigid frame?

Your rigid frame is a living thing. And like any living thing it is always stressed, it is never inert. Your design then should be based on a frame alive with stresses, on its actual behavior. That means that experience should govern in the final design. Consideration of its behavior factors will make for the greatest simplicity and safety.

ACKNOWLEDGMENT

Thanks are hereby expresssed to John Wm. Morgan, Registered Engineer, Pittsburgh, Pa., for his constructive criticism and valuable assistance in the stress analysis.

THE FABRICATION OF Large Diameter Pressure Vessels*

By J. F. BECHTLE†

THE fabrication of large diameter pressure vessels is a highly specialized industry, in which there are relatively few organizations engaged today. The reason for this is that the manufacture of such vessels necessitates the use of certain massive highly specialized equipment such as bending rolls, furnaces, welding trucks, shop space, etc., which the ordinary boiler shop finds itself without. It may be of interest to mention that the number of these vessels made each year is increasing.

A definition of the term "Large Diameter Pressure Vessel" is in order. Any such definition is, of course, arbitrary, but it may be considered that a large diameter vessel is one over 10 feet *in diameter*. For the purpose of this discussion, the terms "thick wall" and "thin wall" will also be defined. It is assumed that thicknesses of $2^1/_2$ inches and over are considered thick wall and contrarily less than $2^1/_2$ inches of thickness will be considered thin wall.

It is characteristic of humans that soon after the introduction of a new type of product, that object is soon accepted as commonplace. This is true of large diameter vessels. Such equipment has been available for perhaps only the past six or seven years and already today the ultimate user considers them in the same category as the smaller diameter vessels. This has not always been the case. Until the middle of the last decade, the pressure vessel user was limited to vessels less than 10 feet in diameter and these were of seamless forged and forged welded construction. Perhaps the chief reason for this is that the needs of the industry did not require vessels of greater size. This fact remains, at least, that the large diameter pressure vessel, as defined in this discussion, is a relatively new type of construction. The important rôle played by welding has been mentioned so often that it is needless to dwell on it further here.

The need for large diameter vessels has been dictated primarily by the petroleum industry, in which it has been continually necessary to produce greater quantities of gasoline and allied products. It may be said that the oil refiners are always confronted with two main problems:

1. How to increase the daily output to satisfy the increasing demands for gasoline.
2. How to increase the yield of the materials being treated to produce gasoline.

It is well known that a method for producing gasoline is the cracking process, in which temperature and pressure play important rôles. The first of the problems mentioned above has been found to be best solved by increasing the amount of crude oil being treated. However, the solution of the second problem—that of increasing the yield—is best solved by increase in temperature and pressure, which increases the yield and improves the quality of the gasoline. The oil refiner thus found himself in need of, first, considerably larger size vessels than were available heretofore, to produce greater quantities, and, second, equipment to withstand higher temperature and pressure to produce higher yields. The result was that the refiners found that their new needs could be satisfied only by relatively few fabricators who had available the necessary equipment, or could afford to spend large sums of money to install heavy machinery such as bending rolls, furnaces, welding trucks, etc., to handle vessels in the neighborhood of 250 tons and X-ray equipment capable of producing ex-ographs, which expose defects within 2% of a shell thickness in the neighborhood of 4 inches.

This discussion will apply, in general, to both thick- and thin-wall large diameter vessels, but will treat especially the thin-wall vessel, because of the greater difficulties of fabricating these structures. This is due primarily to the fact that the thin-wall structures are not stiff enough to be self-supporting during certain stages of fabrication.

There is no reason why any composition suitable for the smaller diameter vessel should not be satisfactory for the larger ones. Accordingly, the common materials used are the plain carbon steels such as the A. S. T. M. A-70, A-149, etc., also carbon molybdenum steel to A. S. T. M. A-204 and allied specifications. It is, of course, necessary to cast very large ingots to produce the large plates necessary, if it is desired to hold the number of welded seams to a minimum. However, the sections can be made from properly welded small plates. The latter, of course, increases costs but must be resorted to on occasion.

There are practically no difficulties encountered in the forming, bending or rolling of thin-wall large diameter vessels, as compared with those encountered in smaller ones, except during the bending of thin-wall large diameter shell sections. For such structures, the plate must be guided, after it passes through the rolls on either side, in order to prevent longitudinal kinks from being formed, when the weight of the plate reaches a point where the material is not self-supporting. These kinks are often very difficult to iron or roll out and they may

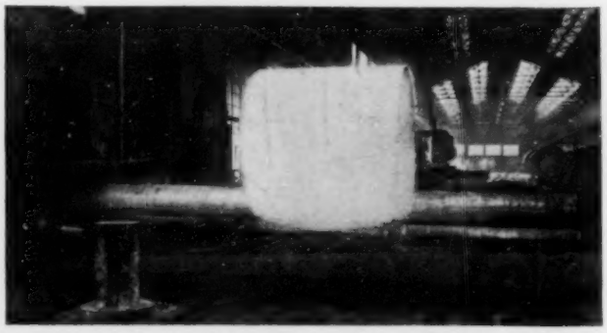


Fig. 1—A Shell Section Being Hot-Rolled After Welding, in Order to Meet Out-of-Round Tolerances

This operation, in effect, also stress-relieves the straight weld for further fabrication, which is helpful in cold weather, particularly on thick-wall sections.

*Paper presented at the Joint Meeting A. W. S. and A. S. M. E., New York Sections, Wednesday, November 15, 1939.

† Welding Engineer, The M. W. Kellogg Company, Jersey City, N. J.

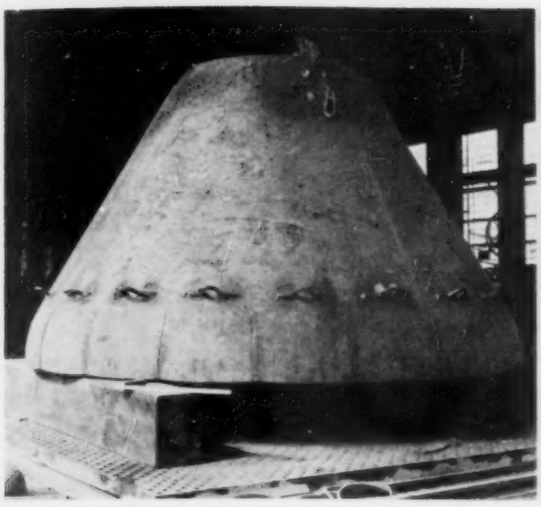


Fig. 2—A Cone for a 16-Foot Diameter Vessel After Slotting and Crimping to Form the Knuckle Radius

This cone was too large as a unit for the steel mill to spin or press the knuckle and we had to resort to forming this knuckle by pressing, in steps, the space between each set of slots. Note the neat contour of the knuckle.

Fig. 3—Cone After Welding of Slots in Knuckle Radius and Attachment of 72-Inch I.D. Nozzle Opening

No forming operation was performed after the welding of the slots, but extreme care had to be exercised during welding, to prevent distortion. Note the well-shaped knuckle and how difficult it is to locate the welds in the knuckle.

be the source of other difficulties further on in fabrication of the vessel, such as the making-up or rigging of internal or external rings, baffles, pans, etc. To prevent these kinks, it is advisable to provide suitable rollers or guides, adjusted so as to offer support to the material being formed. This is easily accomplished by attaching specially built rollers on the arm of a charging or peel crane. Such cranes are considered common equipment in pressure vessel shops for loading or unloading shell plates or rolled sections in or out of furnaces used for heating these parts. Small diameter sections are usually self-supporting and, therefore, do not require the careful handling just mentioned.

To support the individual sections of thin-wall large diameter vessels for straight welding, it is customary to provide stiffeners, usually made from 3-inch or 4-inch pipe, cut so as to be placed across the diameter of the shell and welded on either side of the seam to be welded. After completion of straight seam welding, these stiffeners are removed to permit rolling or rounding-up of each section. It is not customary to use stiffeners of this type for small diameter vessels.

As the next step, these sections are ready for assembly for girth welding or installation of internal and external parts, depending on the size of the vessel. In most cases, it is advisable to install temporary stiffening rings, usually made up of plate material cut to fit the inside of the shell section and bolted together, to permit disassembly and removal through manhole openings, if necessary. These rings are best located near each end of the sections and perhaps one or two located between the end rings for added stiffness.

The rotating rollers used during the making of girth welds have been found to cause "necking-in" of the shell in a circular direction in the vicinity of these rollers, but this can be prevented by installing temporary internal stiffening rings. This is a common occurrence when the vessel is large in diameter and thin-walled together with the added weight of manholes, nozzles, internal pans, etc.

If this "necking-in" occurs at, or close to, a welded internal member, it may be the cause of cracked welds or

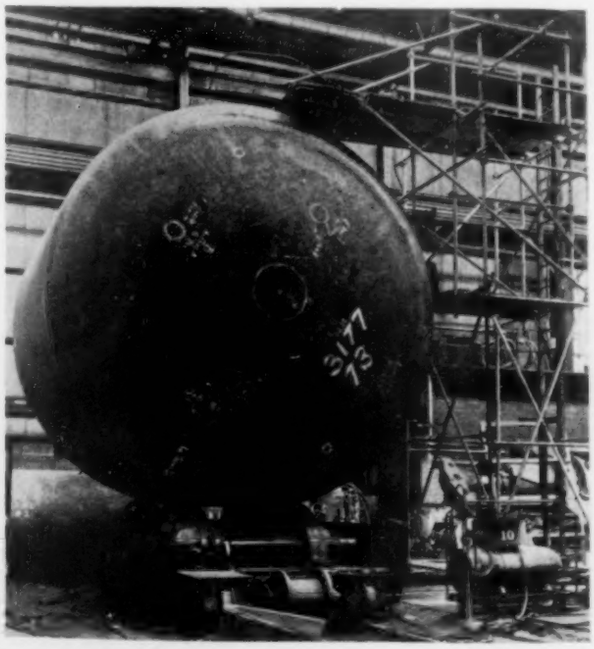


Fig. 4—A 16-Foot Diameter Top Head, Having Been Rigged to Shell Section Prior to Welding

This head is made from two plates welded and X-rayed in our shop while in flat plate form, and returned to the mill for forming.

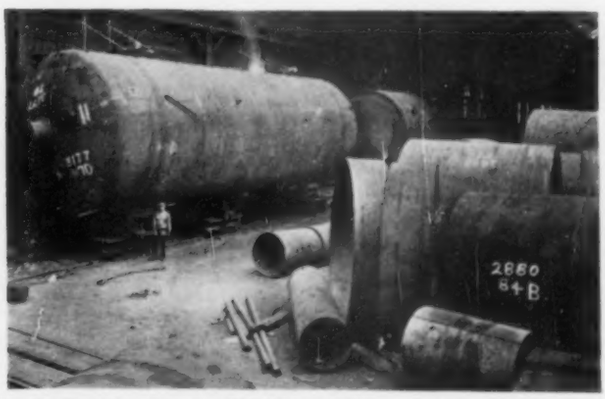


Fig. 5—The Last Circular Weld Being Made in a 16-Foot Coke Drum

In the background shows a single section having the nozzles and miscellaneous parts welded in place.

Fig. 6—A 16-Foot Diameter Cone Girth Seam Being Locally Stress-Relieved

This furnace can be enlarged to accommodate a 20-foot diameter vessel.

Fig. 7—A 15-Foot Diameter Vessel Having the Last Girth Seam Rigged Prior to Welding

Note that there are seven sets of rollers (two rollers per set) used to support the vessel during welding, in spite of the fact that the vessel is 2 1/16 inches thick. In addition, there are a number of temporary stiffening rings assembled on the inside, installed for fabrication only.

Fig. 8—A 12-Foot Diameter Tower 80 Feet Long, the Entire Internal Surface of Which Is Completely Lined with a Corrosion-Resistant Alloy Material

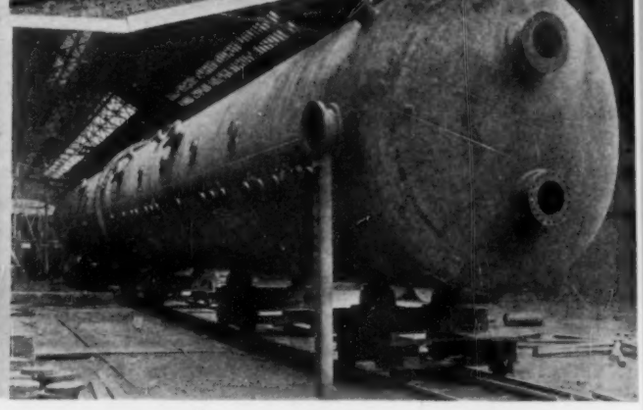


Fig. 9—A 13-Foot 6-Inch Diameter Vessel 1 3/8-Inches Thick x 125-Feet 0-Inch Over-All Length, Being Rigged for the Last Girth Weld

distorted parts. These parts can be straightened and repaired, but it is very difficult to remove the shell distortion called "necking-in" and might be the cause for rejection of the vessel.

Now we are ready for "Stress Relieving." Due to the loss in rigidity of the material at the stress-relieving temperature, which is approximately 1200 degrees Fahrenheit, these internal stiffening rings should be left in place, in order to combat the tendency to sag. It is not customary to use stiffening rings in small diameter vessels during stress relieving, as these structures are generally self-supporting.

During the hydrostatic testing operation, it is advisable to adequately support the vessel, not only with internal rings, but also with suitable timbers or supports externally, together with saddles or chocks shaped to the outside contour of the vessel.

Let us consider a vessel 13 feet 6 inches in diameter by 1 3/16 inches thick x 120 feet long. This vessel, when filled with water for hydrostatic testing, would weigh approximately 1,735,000 lb. This weight, if supported by only two or three timbers, would, no doubt, flatten at the location of each support, which again might result in many difficulties such as distorted members, cracked welds, etc., which would be difficult to straighten out satisfactorily.

For small diameter vessels, it is not necessary to use as many supports as for large diameter ones.

It is also advisable to leave these stiffening rings in place while X-raying, as it is necessary to rotate the vessel during this operation, which would tend to cause "necking-in," as described above.

Some of the special considerations necessary in the fabrication of large diameter pressure vessels are as follows:

1. Source of supply for formed heads, cone pieces, etc. Not every steel mill is equipped to furnish heads over 12 feet in diameter and, therefore, it might be necessary to purchase the larger diameter heads from the very few sources available. A check must be made with the railroad authorities for clearances. Quite frequently the large diameter heads require flat circle sizes larger than can be produced from a single plate; therefore, it is necessary to ship two rectangular plates to the fabricator of the vessel or some other qualified welding company having the necessary equipment, such as welding and X-ray machines, etc. The flat plates are welded, X-rayed and gas-cut to the proper circle size. In some instances, before returning the flat circles to the mill for the forming operation, it is necessary to flange down the edge to form a smaller circle, in order to allow proper railroad clearances.

2. Crane capacity in fabricator's shop must be considered, as generally large diameter vessels having the usual number of external and internal miscellaneous parts weigh considerably more than the average weight of smaller diameter vessels and might easily exceed the safe lifting capacity of such equipment.

3. Furnace capacity for the various heating operations, such as heat to bend, heat to roll and stress re-

Fig. 10—Vessel Completely Fabricated

This vessel was shipped to Beaumont, Texas, via all rail. Note that all shell connections are located in one quadrant of the shell, in order to clear certain fixed obstacles en route to Texas. Note also the number of rotating rollers used to prevent distortion of shell and cracking o linternal welds. This vessel had numerous temporary internal stiffening rings installed for all fabricating operations. Some were removed through the manhole openings, after this vessel was securely blocked on the freight cars. Several of these rings were left in place in the vicinity of the freight car blocking to be removed in the field.

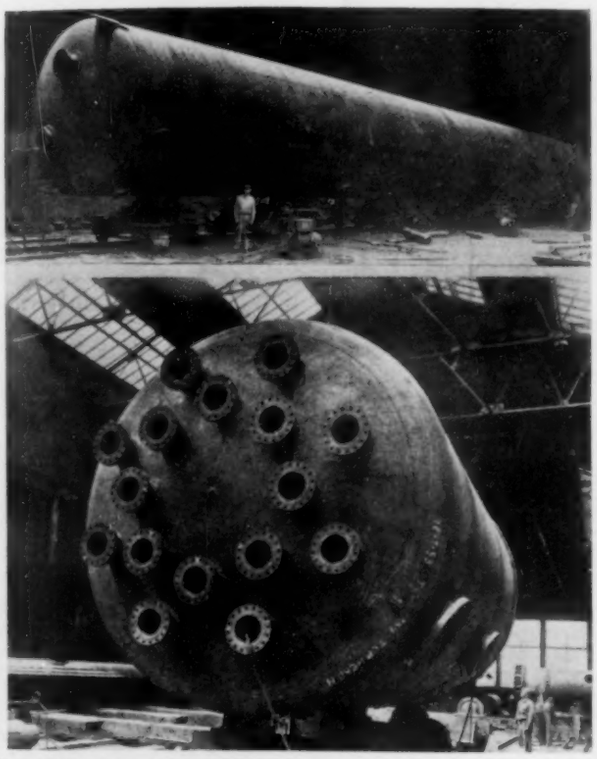


Fig. 11—Another 13-Foot 6-Inch Diameter Vessel with Sixteen 10-Inch Nozzle Connections in Top Head

Extreme care had to be exercised to prevent distortion of the head during the welding of these nozzles. After the nozzles were completely welded to the head, the complete head assembly was placed in a furnace and stress-relieved, prior to welding to the shell section. This precaution is taken to prevent cracking around the nozzle necks after welding.

lieving, must be considered before actual fabrication is started.

4. In some cases, removal of large diameter vessels from the fabricator's shop may prove difficult, if not checked beforehand.

5. *Transportation.*—Another serious problem presents itself in the transportation of the vessels from the manufacturer to the site of erection. If all-rail shipments are considered, it is necessary that a careful check be made with the railroad authorities involved, to ascertain if any obstacles prevail. It is often necessary to remove telegraph poles, tilt tracks to clear fixed structures, sink tracks to clear bridges, etc. If shipment in this manner is impractical or impossible, rail and water shipments are often considered. Here, again, a thorough check must be made with the railroad authorities. Two years ago we were confronted with the problem of shipping several 16-foot diameter vessels to Whiting, Indiana. After a complete check as to the best means of transportation, we were forced to accept the only practical way, namely, by transporting the vessels by rail to the waterfront, where they were placed in New York Bay, and then towed by tugboats up the Hudson River, through the Erie Canal, Lake Erie, Detroit River, Lake St. Claire, St. Claire River, Lake Huron, Lake Michigan and finally to Whiting, Indiana.

Such special considerations, as listed in this discussion, are not associated with smaller diameter vessels, except on extraordinary occasions.

In summing up, it may be said that the differences involved between the fabrication of large diameter pressure vessels as compared to those of smaller size are, mainly, the heavier equipment needed, the need for adequate support to the sections during fabrication, together with large furnaces, shop space, etc.

In conclusion, it may also be said that the fabrication of these vessels is limited in size, only by the transportation facilities existing between the manufacturer's plant and the site of erection

Flame Hardening of Way Surfaces of Machine Tools*

By F. C. DULL†

ANY development that reduces wear of sliding way surfaces of machine tools to such a revolutionary extent as does flame hardening—such a development is a matter of great importance to industry.

Wear of the way surfaces of machine tools has naturally always been a problem in manufacturing plants from the earliest days of machinery history. The cost to industry of wearing and scoring and galling of way surfaces in the life of equipment, rejected products, and the general inefficiency that results has added up to uncountable millions of dollars.

The significant thing is that the problem is becoming increasingly serious and that its relative cost is growing. For wear of the vital parts of machine tools becomes proportionately costly as the demand for accuracy increases. In recent years the demand for accuracy in metal parts, even in the high productive plants, has increased to previously unattainable limits. There are good-sized and rapidly growing industries, such as the aircraft industry, whose entire success depends upon the extreme accuracy of all functioning parts. Limits of half a thousandth are now common practice.

Today it is more important than ever that the ways of lathe beds be made extremely resistant to wear. With the development of tungsten carbide cutting tools, lathe spindle speeds are operating up to 5000 r.p.m. and cuts are being taken never before considered practical. Higher speeds and the removal of more metal call for more power, all of which tends to increase wear.

Most other elements of modern machine tools have been improved to meet the new requirements. Practically all gearings are of the anti-friction type. Shafts and gears are of alloy steels and a great number of parts are hardened and ground. Yet, until recent application of the flame-hardening process, no completely satisfactory solution had been found to the problem of wear on bed ways.

Lathe beds start to wear the very first day they are put in use. From that day on, scoring, scratching, galling and wearing continue until the combination of these

* Paper presented at Annual Meeting, A. W. S., Chicago, Oct. 22 to 29, 1939.

† The Monarch Machine Tool Company, Sidney, Ohio.

elements completely destroys the machine's original accuracy and efficiency.

Many attempts at solving the problems have been made or tried. At first, the iron along the way sections was cast against a chill, but chilling introduced and set up internal strains. The low-strength, open-grained iron which was used (because chilled, close-grained iron was not machinable) was not uniformly hard in the finished way section.

Most of you are familiar with a later attempt to provide against wear. I refer to the hardened and ground steel wear strips. These have proved reasonably satisfactory. However, the many drilled holes in the bed way section necessary for attaching the wear strips certainly reduce the strength of the bed and regardless of how well they are attached there is the threat of the hold-down screws getting loose.

You men in the welding industry are undoubtedly interested in the attempts at making entire beds of welded steel construction. You know and we know there are many advantages to an all-welded design. It is my belief that most machine tool builders have found, at least at this stage of its development, that all-welded steel construction is too expensive. It must also be stated that the all-steel base has no appreciable gain in increased life. This at any rate is true as it relates to lathe beds since the ways of the welded bed must still be hardened. Since machine tool bases are usually so hard and irregular in shape and section, heat treating and quenching them in their entirety is out of the question.

I do not mean to imply that all these various measures have been completely ineffective—instead they represent definite progress in the right direction and have been most effective and practical in the processing of many parts.

About five years ago we at Monarch began experimenting with flame hardening. The first attempts were immediately promising although we were not without difficulties.

The first problem, and the one which critics of the idea insisted would make flame hardening impractical for lathes used for extremely accurate work, was that of distortion. Another problem was to get the required hardness without any possibility of the hardened layer cracking or spalling away from the unhardened metal beneath. With these difficulties solved there still remained the problem of grinding the long vee and flat way surfaces to the extreme tolerances required.

After $3\frac{1}{2}$ years of experimenting and testing these and numerous other difficulties were solved. At this time the special equipment required was designed and perfected, and the production of flame-hardened lathe beds is now a standard practice at the Monarch plant. Lathe beds weighing as much as $7\frac{1}{2}$ tons have been flame hardened with ways unmachinably hard and finished to a tolerance of 0.0005 inch. A test machine running day and night in our plant for almost 20 months shows no evidence of score or spalls or even scratches on the way surfaces. Another lathe, the bed of which is flame hardened, has been in use under actual operating conditions for almost four years. This has been subject to frequent test and today has the same accuracy and is otherwise in the same perfect condition as it was the day it was placed in service.

A composition of Monarch lathe beds is specified to run as follows:

	Maximum	Minimum
Total carbon	3.20%	2.80%
Combined carbon	0.75	0.55
Silicon	2.00	1.70
Manganese	1.00	0.70
Nickel	1.50	1.00
Phosphorus	0.15	1.00
Sulphur	0.10	1.00
Chromium or molybdenum	0.25	1.00

The mix to the cupola consists of 50 to 65% steel railroad rails and the balance pig iron of high grade as needed to bring the amounts as indicated. The variation in the percentage of steel is related to the size of the metal structure. The iron thus produced is composed of a fully pearlitic matrix, similar to that in high-grade hard steel. Like steel, this iron responds to heat treatment.

We have found that the lower the hardening temperature the less will be the distortion during flame hardening. Since the amount of heat applied to the surface must be controlled to prevent fusing or burning a low-hardening temperature is obviously desirable. A lower heating temperature has a generally milder action and a more gradual blending with the under body, resulting in a more evenly hardened surface. Castings of the composition described above respond to heat treatment and can be fully hardened from a low temperature of about 1320° F.

We are able to produce castings capable of being flame hardened to the desired depth without heat checking and we are also able to get a hard wear-resisting surface with a minimum of distortion.

Beds are flame hardened in a specially designed water tank. They are submerged or immersed in a continuously circulated water with only the surfaces to be treated exposed. Since the bed construction of Monarch Lathes includes 2 vees and 2 flats six oxyacetylene torches or tips are used. In this way we treat both sides of both vees and both flats at one pass. The quenching is accomplished by means of water passing through the tips located at a fixed dimension in back of the flame.

The carrier supporting the tips moves lengthwise over the tank at a predetermined rate of travel depending upon the size of the bed being hardened and the depth of hard surface desired. Some variables which had to be worked out by experience are as follows: first, the distance of the flame from the surface to be treated; second, the volume of the flame; third, the distance the water quench is in back of the flame as well as the volume of water; and fourth, the rate of travel of the flame.

For all beds in lathe sizes from 12 inches on up, a minimum depth of hardness of $\frac{1}{8}$ inch is standard.

By localizing the heat at the burners and by means of a circulating water bath, and quenching with the proper water pressure, distortion is held to a minimum. The average distortion in a bed of comparatively small structure and as long as $8\frac{1}{2}$ feet, hardened to a depth of from $\frac{1}{8}$ minimum to $\frac{1}{4}$ inch maximum, is approximately 0.008 inch. This distortion is of course eliminated in the grinding and the final tolerance is 0.0005 inch or less in the over-all length.

Of all the tests that have been made probably the best is the one to which we have already referred. This is the unit consisting of two lathe beds, the one unhardened, the other with flame-hardened ways. Each lathe carriage is loaded with a 500-lb. weight subjecting the bearing surfaces to what would be normal operating pressures. A crank arrangement operated by an electric motor causes the carriages to move a distance of one foot every three seconds. As stated above cast-iron dust filings are automatically fed to the bearing surfaces in such a way that again normal operating conditions are duplicated. After almost 15 million pass, the unhardened bed is badly scored and shows no wear whatsoever.

The most conclusive proof of practicability of the flame-hardened lathe bed is the universal satisfaction as reported by upward on one thousand users of the flame-hardened development.

To further prove that the hardened surface is firmly blended into the base metal hundreds of test sections have been subjected to many tests including flexing under hydraulic pressure and various impacts. In every case pressures had to be increased to the point where the piece itself would fail before spalling took place.

Just as welding has brought to industry enormous savings possible through no other medium, so we at Monarch who undertook to pioneer the new method of making lathe beds resistant to wear, know that this development will have far-reaching effects throughout industry.

Air Circuit Breakers For Resistance Welding Machines

By WAYMAN A. HOLLAND*

A DEVICE to provide proper protection for resistance welding machine circuits must have special characteristics. It must allow normal heavy welding inrush currents to pass unnoticed, yet must instantly interrupt damaging overcurrents or short circuits and then be capable of being quickly reclosed to restore the supply power. An air circuit breaker such as described here meets these requirements.

A typical breaker is illustrated in Fig. 1. This is a compact, instantaneous, automatic overcurrent air circuit breaker with high-speed and high interrupting capacity. It is equipped with arc quenchers consisting of an arrangement of metal pins within an arc chute above the arcing contacts of the breaker. The arc is confined within this chute, and is split up by the pins and cooled, so that the arc energy is rapidly absorbed, resulting in extremely quick interruption, of the order of less than one cycle (0.016 second). An instantaneous magnetic tripping device causes the breaker to open and thus clear the circuit before the high currents can damage the equipment. This consists of an electromagnetic circuit actuating an armature to give a hammer blow to the tripping lever when the current reaches the value for which the setting is made on a "calibration plate." This tripping is made instantaneous so as to clear the circuit as quickly as possible when dangerous overcurrents occur, yet the setting is such that normally heavy currents will not cause its operation.

* Switchgear Division, General Electric Company.

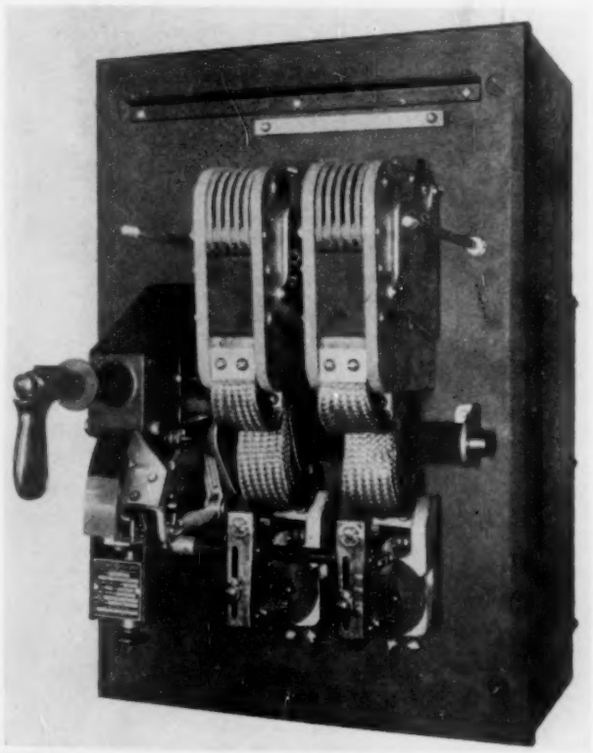


Fig. 1—Instantaneous Air Circuit Breaker, Double-Pole Manually-Operated, for Resistance-Welder Protection with Pull-Box (Cover Removed)

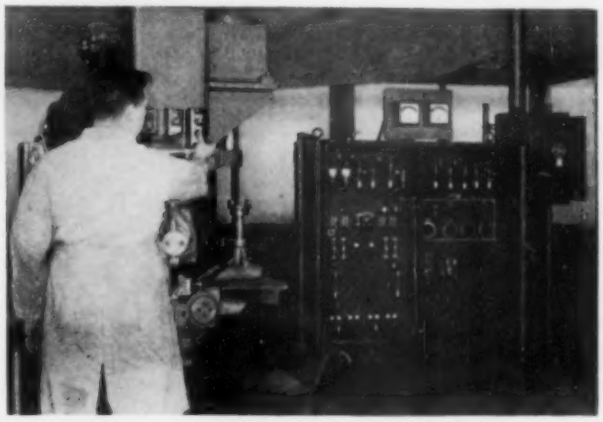


Fig. 2—Push Button Control of Electrically-Operated Air Circuit Breaker for Protection of Resistance Welding Machines

The breaker is made in single-pole or double-pole units, manually or electrically operated, enclosed in a metal housing, with pull-box, for machine or any flat surface mounting, or arranged for live-front or dead-front switchboard mounting. Electrically operated breakers are used when it is desired to close, or to open, the breaker by means of a convenient pushbutton switch on the welding machine, or other place, remote from the breaker (see illustration, Fig. 2). Trip attachments can be provided for opening the breaker from an emergency button, or from other devices for tripping, such as at times of "no water flow" in the transformer, voltage below normal, faulty timing, or when other abnormal conditions prevail.

These breakers are particularly appropriate for the protection of welding machines equipped with thryatron or ignitron control. Two tubes must be used with each circuit, connected in parallel, to serve as a single-pole device because each tube conducts current in only one direction and under normal conditions these provide ab-

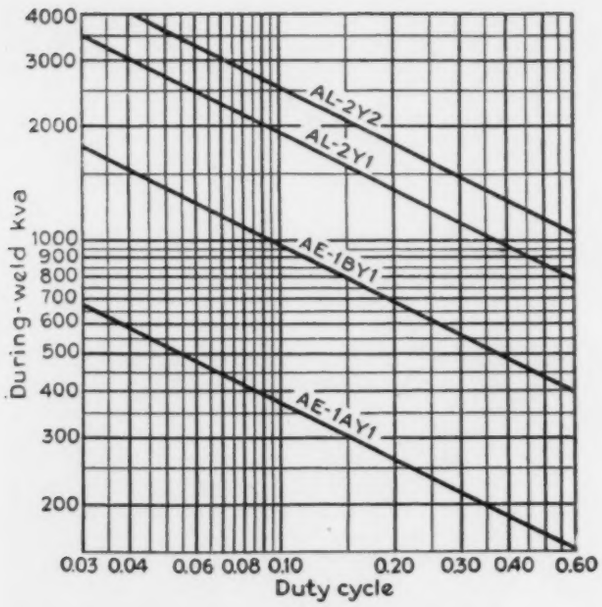


Fig. 3—Maximum Loading Curves in "During-Weld" Amperes, for Air Circuit Breaker Resistance-Welder Protection

solutely uniform current control. Failure of one tube to function properly causes instantaneous transient high-current with high d. c. components. These may cause damage not only to the remaining tube, but also to the transformer, and cause defective welds, with consequent shutdown and loss of production, as well as other losses. Failure of a power tube to function properly should, therefore, be indicated immediately. The air circuit breaker, with its instantaneous trip, will show the tube failure by opening the power circuit. A fuse or a thermal device may fail to open under these transient conditions because the sustained effects may not last long enough to operate them.

CHOICE OF BREAKER

It is of course essential that the breaker chosen have adequate interrupting capacity, and this is dependent largely upon the capacity of the transformers, or other sources, supplying the power. Breakers are available with interrupting ratings of 10,000, 20,000 and 40,000 amperes.

Breakers for welding machines must be applied in accordance with the duty-cycle requirements of the machine or welding operation. The duty-cycle is defined as the percentage of time the current flows each minute.

The curves in Fig. 3 show the maximum "during-weld amperes" for four different sizes of breakers and the curves in Fig. 4 show the "during-weld amperes" translated into "during-weld kva." at 440 volts. The curves are given both in amperes and kva. for convenience in application, depending on whether amperes or kva. are specified in the requirements.

The selection of the proper size breaker is readily made from these curves, the size to use being the one whose maximum load curve is just above the greatest during-weld load at the duty-cycle value for the particular application.

As an example assume a "during-weld load" of 600 kva., 440 volts, 0.15 duty-cycle.

From Fig. 4 it is seen that the breaker No. 1, for duty-cycle 0.15, is good for only 300 kva. and therefore it is not adequate, but that the No. 2 is good for almost 800 kva. This is well above the requirements and, provided that this breaker has adequate interrupting capacity to meet the requirements of the system, is the one to use. If the duty cycle had been, say, 0.40 instead of 0.15, it is seen that a breaker No. 3 would be required because at 0.40 duty-cycle the breaker No. 2 is good for only 500 kva.

Thus by the use of air circuit breakers, with especially designed instantaneous trip arrangements, discriminating between normally heavy during-weld currents and short circuit currents, proper protection is afforded resistance welding machines, with efficient operation and without undue service interruptions.

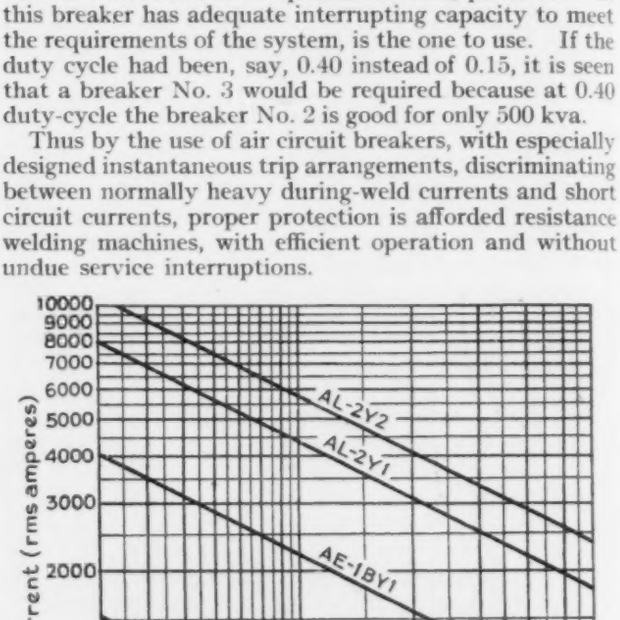


Fig. 4—Maximum Loading Curve in "During-Weld" Kva. at 440 Volts, for Air Circuit Breakers for Resistance Protection

PRODUCTION BRAZING and WELDING of Light Gage Materials*

By L. AYERS†

MODERN firms, with their diversities of production, require tools capable of meeting demands for design changes at low cost and with a very little loss of production.

Welding apparatus has played a very important part in the meeting of this requirement.

In the manufacture of our lubrication equipment, designs have been achieved that would be impractical, if not impossible, with any other method than welding.

It might be well to say here that time did not permit the making of illustrations of the equipment covered by this paper.

In the experimental sheet metal division of our company, we are able to lay out the component parts of our lubricating and refrigeration cabinets by triangulation, forming them into graceful, flowing lines by hand or hand-operated machines, then joining the parts or sections by oxyacetylene welding, thus saving the cost of expensive experimental dies, enabling the use of streamline design with no projections of rivets, bolt heads or seams.

The production of air domes for our motor oil dispensers requires a unit capable of operating at an internal air pressure of 300 pounds per square inch.

These domes consist of a heavy steel base and a steel cylinder, 2 inches in diameter, having a wall thickness of sixty-two thousandths of an inch.

The top of the base is machined and inserted in the open end of the cylinder, with two thousandths of an inch clearance allowed between the outside diameter of the base and the inner wall of the cylinder.

A wire ring insert of Easy Flo brazing alloy, melting at 1175° F., is fluxed and preplaced in a groove provided in the base prior to assembly with the cylinder.

The brazing alloy ring is made from $^{3}/_{64}$-inch wire, formed into rings by a coil-winding machine.

The assembled unit is heated around the base with an oxyacetylene flame to a temperature required to melt the inserted alloy.

The unit is then filled with oil and must withstand a maximum oil-pressure test of 1000 lb. internally, after which it is tested for air leak at 250 lb. air pressure.

On an experimental test of one of these units, the unit was placed inside of a safety cage and tested at 3000 lb. internal oil pressure at which pressure bulging of the cylinder walls occurred.

An examination of the unit following this test disclosed no sign of failure in the brazed joint.

As the operating pressure of the unit is only 300 lb. air pressure, we are assured of a safety factor of at least 9 to 1.

On our hand pumps for industrial machine lubrication, all pressure tank connections are brazed with the same brazing alloy to ensure permanently tight and strong joints.

While our concern makes use of almost every type of welding, such as butt, flash, spot, projection, metallic arc, oxyacetylene brazing and welding, the low-temperature brazing materials are used in the production of a great number of items due to the high strengths obtained and the low heats required, thus lessening distortion of the part and subsequent machining of the finished assembly.

Our lubricant flow meters, consisting of the hand pump meter, the barrel pump meter and the drum pump meter, were formerly of die-casting construction.

These units were recently redesigned into a steel welded and brazed assembly, with the following results:

Higher operating pressures were possible than were formerly obtained.

Changes in design can now be made to meet the changing requirements of industry at a minimum of cost and time.

A greater strength in the meter body is obtained, which is resistant to the rough handling to which these meters are often subjected.

Maintenance costs have been considerably lowered, and repairs to damaged equipment in the field have been simplified.

Production costs have been reduced slightly.

The cylinder of the present meter gun is a seamless steel tubing, $3^{29}/_{64}$ inches long and 2.375 outside diameter, with a wall thickness of 0.120 inch.

A clip assembly is spot welded to the cylinder, after which the outlet disk is firmly riveted into place on the outside wall of the cylinder.

The disk is then brazed by means of a preplaced brazing washer insert, and the aligning rivet removed.

The mechanism-supporting bracket is spot welded to the regulator body after which the bushing blank is installed in the body and staked into place.

The bracket and bushing blank are then brazed to the regulator body by means of a preplaced brazing insert, and the entire assembly is installed in the end of the cylinder and brazed in place, again using a preplaced brazing insert.

The next operation is the installation of the recording mechanism. The cap and adapter ring are brazed together and are then installed on the threaded end of the cylinder.

The assembled meter gun is tested, and must maintain an internal air pressure of 250 lb. per square inch.

On the hand lubricator meter, a handle is spot welded to the cylinder wall prior to assembly.

The tractor buckets, used for holding lubricants, are seam welded on the body and end seams, and the foot bracket is braze welded with the oxyacetylene flame and bronze rod.

Many other applications of welding and brazing on our refrigerators, radios, auto accessories and alemite equipment might be discussed, and new applications are being constantly developed, but the short time given for the preparation of this paper precluded any opportunity to compile the required data necessary.

* Paper presented at Annual Meeting, A. W. S., Chicago, Oct. 22 to 29, 1939.
† Stewart Warner Co., Chicago, Illinois.

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WELDED STRUCTURES

Under the Bureau of Yards and Docks Navy Department*

By COMMANDER C. A. TREXEL (CEC) U. S. N.

THE BUREAU OF YARDS AND DOCKS, AND ITS ACTIVITIES

THE Navy consists of ships, and when the average American speaks of the Navy, he visualizes battleships, aircraft carriers, cruisers, destroyers and submarines. But the Navy also includes a shore establishment. Aside from men, the main components of a Navy are in fact ships including aircraft, and their bases. The importance of bases to a fleet is sometimes overlooked, yet a Navy of ships without bases at their disposal would become impotent. Without facilities to replenish fuel and supplies and to obtain needed repairs to hull and machinery and cleaning of bottoms, ships would soon become immobile, and in time would be stranded and sunk. It is the naval bases and accessory facilities of the Naval Shore Establishment which make the fleet effective and which, by multiplying the number and power of usable ships, are themselves the equivalent of ships. As Captain Dudley W. Knox, eminent retired naval officer, historian and analyst has said:

"The ships with bases at their disposal are the ships that count."

The Naval Shore Establishment is an active business organization representing an investment of one billion dollars and comprising a large number and variety of activities. It includes Navy Yards, submarine, destroyer and air bases, supply fuel and ordnance depots, gun and powder factories, radio stations, research and experimental laboratories, training stations, naval hospitals and the fine educational equipment for training midshipmen and developing young officers at the U. S. Naval Academy at Annapolis, Md. At the present time this shore establishment is being augmented by the construction of seven new outlying air bases to give warning of unfriendly approach toward our continental shores—a significant recognition of the growing power and range of aircraft.

The design and construction of the stations comprising this vast and far flung shore establishment which extends from the Panama Canal Zone to Alaska, and from the Carribean to Hawaii, the Philippines and China, are the primary concern and responsibility of the Bureau of Yards and Docks. The Bureau of Yards and Docks is charged by statute and by Departmental regulations with the design and construction of all public works and public utilities of the Navy and with making necessary provision for expansion and the establishment of new stations in time of war. The designs for the diversified structures required at these Naval Bases are prepared by this Bureau and the work in the field is carried out under the direction of the officers of the Civil Engineer Corps, U. S. Navy, who constitute its Administrative Staff.

DEVELOPMENT OF WELDING IN THE NAVY

There are many structures at the various stations of the Naval Shore Establishment, in the construction and repair of which, welding can be used to advantage. Hangars, shops, storehouses, bridges, piers, bulkheads, shipbuilding ways, radio towers, water and fuel tanks, boilers, piping, floating and bridge cranes, dry dock caissons, buoys, trucks, railroad rolling stock and many others lend themselves readily to welding. During the past fiscal year, $45,000,000 worth of such structures under the cognizance of the Bureau of Yards and Docks were being constructed by contract and a greater volume

* Presented at Annual Meeting, A. W. S., Chicago, Oct. 23 to 27, 1939.
The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the Navy Service at large.

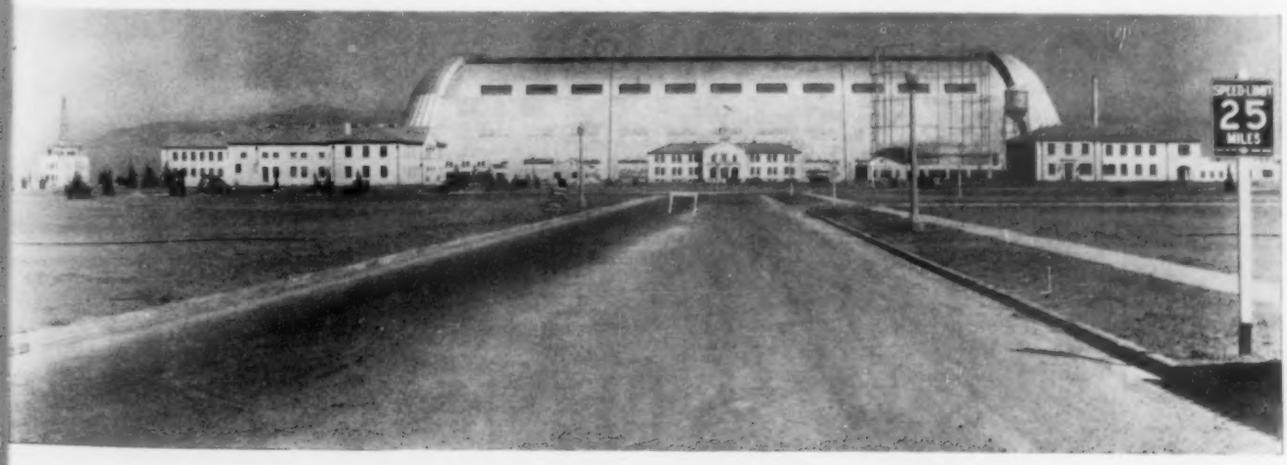


Fig. 1—General View Air Station, Sunnyvale, Cal., Showing Airship Hangar

Fig. 2—David W. Taylor Model Basin, General View of Building Group

by day labor. In public works of this character and magnitude there is of course a field for the utilization of welding on a large scale but it is only within the past two years that extensive use of welding on naval shore structures has been made. As in the case of commercial practice, welding first found extensive application in the Navy in the construction of ships, where its adoption 10 years ago was brought about primarily by disarmament treaty restrictions on displacement, which placed a premium upon weight reduction. The welding engineers of the Bureau of Construction and Repair, Navy Department, which is concerned with the construction of ships, pioneered in the application of welding to ship hull construction, and many of the developments have since found their way into standards, codes and general practice.

ADOPTION OF WELDING ON NAVAL STRUCTURES ASHORE

The considerations which dictated the adoption of welding for floating structures did not however have equal application to the design of buildings. Early experience indicated no saving of cost by welding, and there were other factors which acted to delay its adoption for shore structures. Until recently, limited competition retarded the adoption of welded designs. The Bureau accomplishes most of its construction work under contract, and the adoption of welding was accordingly dependent upon the acceptance by steel fabricators and erectors of this means of steel fabrication. It has been only within the past few years that contractors in the building industry have equipped themselves to use welding economically and to compete successfully on structural work. A few unfortunate early experiences with bare rod welding had built up in the minds of some structural designers, a prejudice against welding which has been overcome only by years of successful welding with coated electrodes. The difficulty in determining the soundness of welds and the qualifications of the welders to make adequate welds was a particular deterrent to the adoption of structural welding. Unfamiliarity of structural steel designers with proper welded design details, lack of design standards, and consequent inability to produce welded designs as quickly as riveted, often eliminated welding from consideration on projects which were particularly suited to this form of construction.

STANDARD SPECIFICATIONS

Before welding could be adopted on important Bureau projects involving the safety of human life, it was essential that adequate standards of design, inspection and qualification of welders be available. The Bureau of Yards and Docks in the early part of 1938, began preparation of two specifications, one covering welding design and the other welding inspection. In the preparation of these specifications, use was made of various codes, available test data, and suggestions of welding engineers of other bureaus of the Navy Department and representatives of equipment manufacturers and industrial companies engaged in welding. The suggestions obtained and the comments made by the industry on the preliminary drafts were of great value in the preparation of the final draft of these specifications. They are accordingly, in a sense, compilations of the best theory and practice obtainable. They are now in use though still undergoing change. The basic stresses for welded joints follow closely the stresses recommended by the AMERICAN WELDING SOCIETY. The basic stresses for base metal follow those recommended by the American Institute of Steel Construction. Some modifications were made in the Federal specifications for structural steel, to assure a safe limitation upon carbon content. These modified requirements vary slightly from those of the A. S. T. M. specifications for structural steel. They are, however, within steel manufacturers' tolerances and do not involve a premium on the base price. Qualification tests are those required by the Navy Department to qualify welders on ship construction. The guided bend tests, which are now quite well known, are included as a specification requirement. The tests are inexpensive, positive as to interpretation and suitable for field qualification in view of the portability and small quantity of equipment required. Welders able to pass these tests are considered fully qualified to make sound welds suitable for the construction of shore structures.

EXAMPLES OF NAVAL WELDED CONSTRUCTION

The first application of welding on shore structures of the Navy was on secondary members and non-strength parts. In the construction of the large airship hangar (Fig. 1) at Sunnyvale, California, in 1933, over seven miles of seam welding were applied on the deck plates of the mezzanine floor. In the same year, the Bureau designed and constructed at the U. S. Naval Observatory, Washington, D. C., a building with a rotating dome to house the new 46-inch telescope. It was essential that this structure be rigidly constructed and as free from vibration as practicable. All the roof framing, bracing and plates were welded. In the construction of the 250 ton hammerhead crane at Puget Sound in 1933, welding was employed in the fabrication of machinery bases and

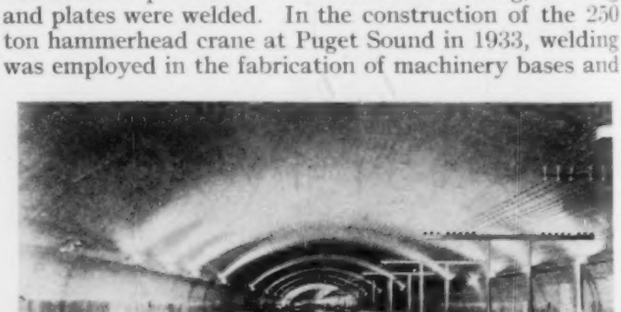


Fig. 3—David W. Taylor Model Basin, Interior View Showing the Larger Towing Basin

for minor accessory fixtures. Welding was employed in the assembly of the reinforcing steel cages at the abutments and top hinges of the long span concrete arches in the Navy's new Model Basin at Carderock, Maryland, near Washington. This $3,500,000 structure which when placed in commission in the near future, will be the world's largest naval model tank and testing laboratory, was designed under the personal direction of Rear Admiral Ben Moreell (CEC), U. S. N., now Chief of the Bureau of Yards and Docks. Fig. 2 shows an exterior view of this beautiful structure and Fig. 3 an interior view of the larger of the two towing basins.

In 1934, welding was permitted on a boiler drum for installation in a power plant ashore and since that date all boiler drums have been welded and inspected under the A. S. M. E. Boiler Code. Among other power plant installations, the Bureau has recently designed an entire new plant for one of the principal Navy Yards. This plant is designed for 650 lb. pressure and 750° temperature. The boiler drums and, with minor exceptions, all power plant piping are to be welded. Chrome molybdenum steel will be used for valves and fittings and carbon steel for high pressure piping. Stress relieving of welded joints by means of electrical unit heaters is

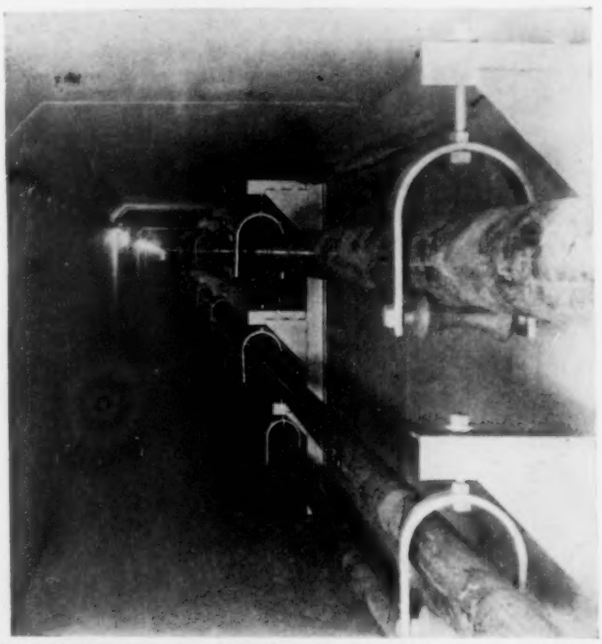


Fig. 4—Welded Steam and Condensate Lines in Service Tunnel, Naval Academy, Annapolis, Md.

being required. In 1934, the Bureau began welding power plant piping. Today practically all power plant piping and much of the distribution system piping is welded. Fig. 4 shows welded gas and steam lines recently installed in new service tunnels constructed at the U. S. Naval Academy, Annapolis, Maryland. At the new outlying air bases now being constructed in Alaska, the Western Pacific and San Juan, all pipe lines for the distribution of steam, air, water, fuel oil and gasoline will be of steel, welded to minimize shattering from bomb blasts. While not a new application, this is perhaps a new reason for specifying welding. The steel gasoline storage tanks at these stations will be underground, and will likewise be welded for the same reason.

Welding has such pronounced advantages in the construction of pipe lines, tanks, buoys, floats, pontoons and barges, from the standpoints of both resistance to corrosion and leakage, and weight reduction, that it is usually specified even though unit costs be higher than for riveted

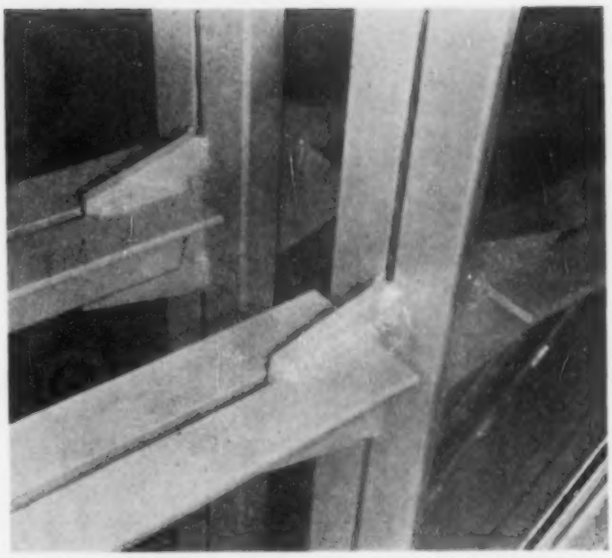


Fig. 5—Fleet Moorings—4-Point Mooring Buoy Showing Interior Welded Connections, Naval Operating Base, San Diego, Cal.

construction. Buoys are usually fabricated by welding alone or in a few cases in combination with riveting. Rivets and welds are not, however, called upon to share the load on a joint (see Fig. 5). Welding of steel floats, pontoons and barges is permitted, and is usually adopted with some saving in cost. The pontoon of a 25 ton floating crane (see Fig. 6) recently constructed for the Norfolk Navy Yard is of welded construction, which resulted in a saving of $2500 in the contract cost, over riveted construction.

Welding affords greater rigidity, and also an appreciable reduction both in weight and in operating costs of moving structures such as railway and automotive equipment and bridge cranes. The Bureau has just completed the purchase of 75 bridge cranes ranging in capacity from

Fig. 6—Bottom and Side Plating 25-Ton Floating Crane, Norfolk Navy Yard

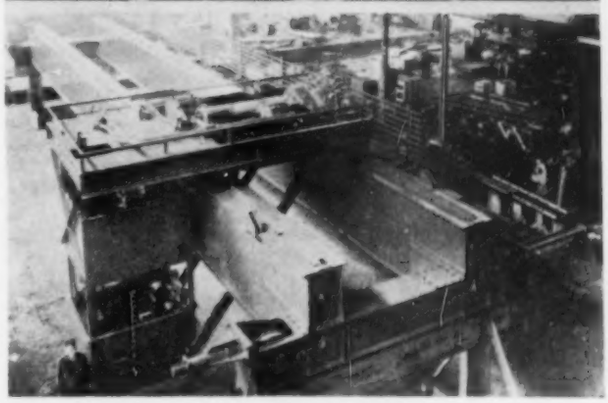


Fig. 7—Welded Bridge Crane

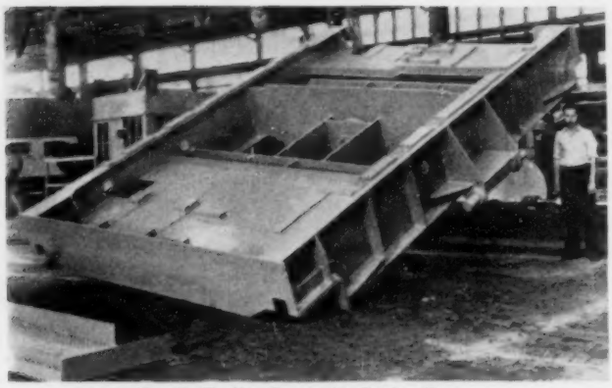


Fig. 8—Trolley Frame for Bridge Crane

2 to 175 tons. The latest Bureau specification permits either welded or riveted bridge girders but requires that end trucks and trolleys be of welded construction. Figures 7 and 8 show the welding practice of one crane manufacturer. Automatic welding heads are used on the long exterior seams of the bridge girders.

Welding has been successfully employed in the construction of a number of steel piers where hard driving or other conditions required the use of steel *H* piles. Figure 9 shows welded steel piers at Key West, Florida. Similar welded steel piers will be constructed at the new outlying air bases where coral or boulders will be encountered. As in the case of piping and gasoline tankage, it is expected that welded steel piers will sustain relatively less damage from bombing.

Welded design lends itself particularly well to rigid frame structures, results in a substantial saving in weight of steel and presents a clean cut structure of more pleasing appearance than the conventional truss roof with its maze of truss members and bracing. The first structure in which the rigid frame design was employed is now nearing completion at the U. S. Naval Academy, Annapolis, Maryland. Modernization of the Mess Hall called for the removal of existing groined arch construction and its replacement with clear span construction. Figure 10 shows a portion of the completed work. The span of the arch is 75 feet. One of the advantages of welding, namely, quietness in erection, was particularly appreciated on this project as building operations were carried on during the academic year. This factor has an appeal on construction projects in thickly populated residential and office areas and especially in the vicinity of hospitals. Another form of welded rigid frame was used for the structural shop and mold loft now being built at the Boston Navy Yard, (see Fig. 11). The clear span is 100 feet. In this design, the 54 inch girder supporting the mold loft floor replaced a conventional 9 foot truss and a slender gabled bent replaced the conventional roof truss, thereby effecting a reduction in the height of the entire building of 9 feet 6 inches and a corresponding saving in the cost of construction and of future maintenance and heating (see Fig. 12). Incidentally it is expected that the treatment of the mold loft ceiling made possible by the welded construction will be particularly pleasing in appearance. A rigid frame type of shop building, the Shipfitters Shop, Portsmouth Navy Yard, has just been placed under contract. To afford a direct comparison of cost, bids for both welded and riveted construction were solicited. The accepted welded design was $14,000 lower on a total cost of $360,000. A rigid frame design has also been utilized for the Structural Assembly Shop, Norfolk Navy Yard. While careful analysis of rigid frames is required, wherever there is a considerable number of identical frames, as in the cases cited, the calculations for the welded design require little more time than the riveted.

Fig. 9—Bent Framing for One of Five All-Welded Piers, Naval Station, Key West, Florida

Welding has also been used extensively on repair work. Figure 13 shows the method of reinforcing, by means of welded stiffener plates, the 600 foot radio towers at Annapolis to carry heavier antennae.

An indispensable piece of equipment in all welding work is of course the oxy-acetylene cutting torch. Recently the Bureau has been experimenting with flame cleaning of new structural steel and plates with a view to obtaining better adhesion of the shop coat of paint on steel intended for overseas shipment or otherwise exposed to severe corrosion conditions.

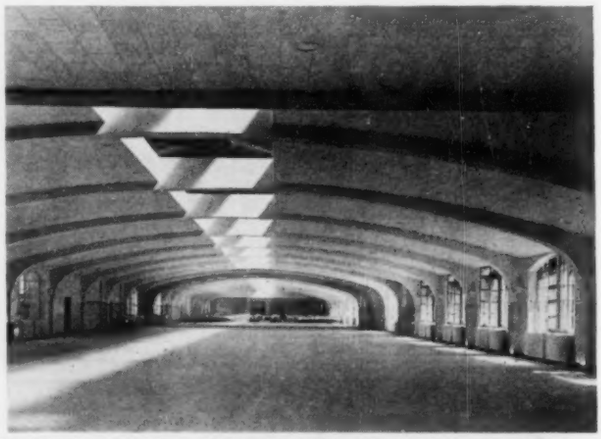


Fig. 10—Interior View of Mess Hall, After Remodeling, Naval Academy, Annapolis, Md.

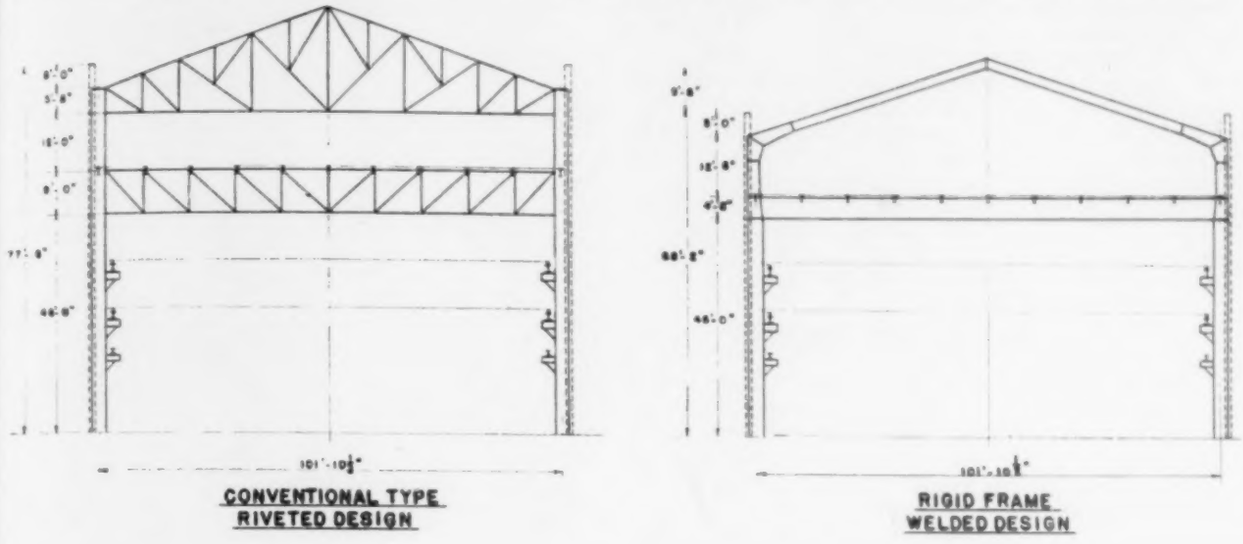
Having in mind the relatively short time during which the Bureau of Yards and Docks has been devoting itself seriously to welding, it will be evident from the foregoing examples of welded structures that the Bureau is definitely committed to welding. There are, to be sure, some large complicated structures subject to heavy stresses such as dry dock caissons, and other such as the 350 ton hammerhead cranes being built at the New York and Norfolk Navy Yards, on which the Bureau is not yet prepared to adopt welded design of main strength members, but this is due in part to the fact that certain technical problems relating to shrinkage and distortion have not yet been completely solved; and also due to the fact that there has not been sufficient opportunity during the past two years to make the necessary studies and designs required for such important structures.

FUTURE OF WELDING

Welding is a fundamentally sound and economical process. Riveting has for many years served as a con-

venient and satisfactory means of joining metal parts, and methods of fabricating and handling riveted work have been developed to a high degree of efficiency. But a joint which weakens the parts being joined, as the

Fig. 11—Drawing Showing Welded Conventional Riveted Design and Welded Rigid Frame Design, Structural Shop, Navy Yard, Boston, Mass.



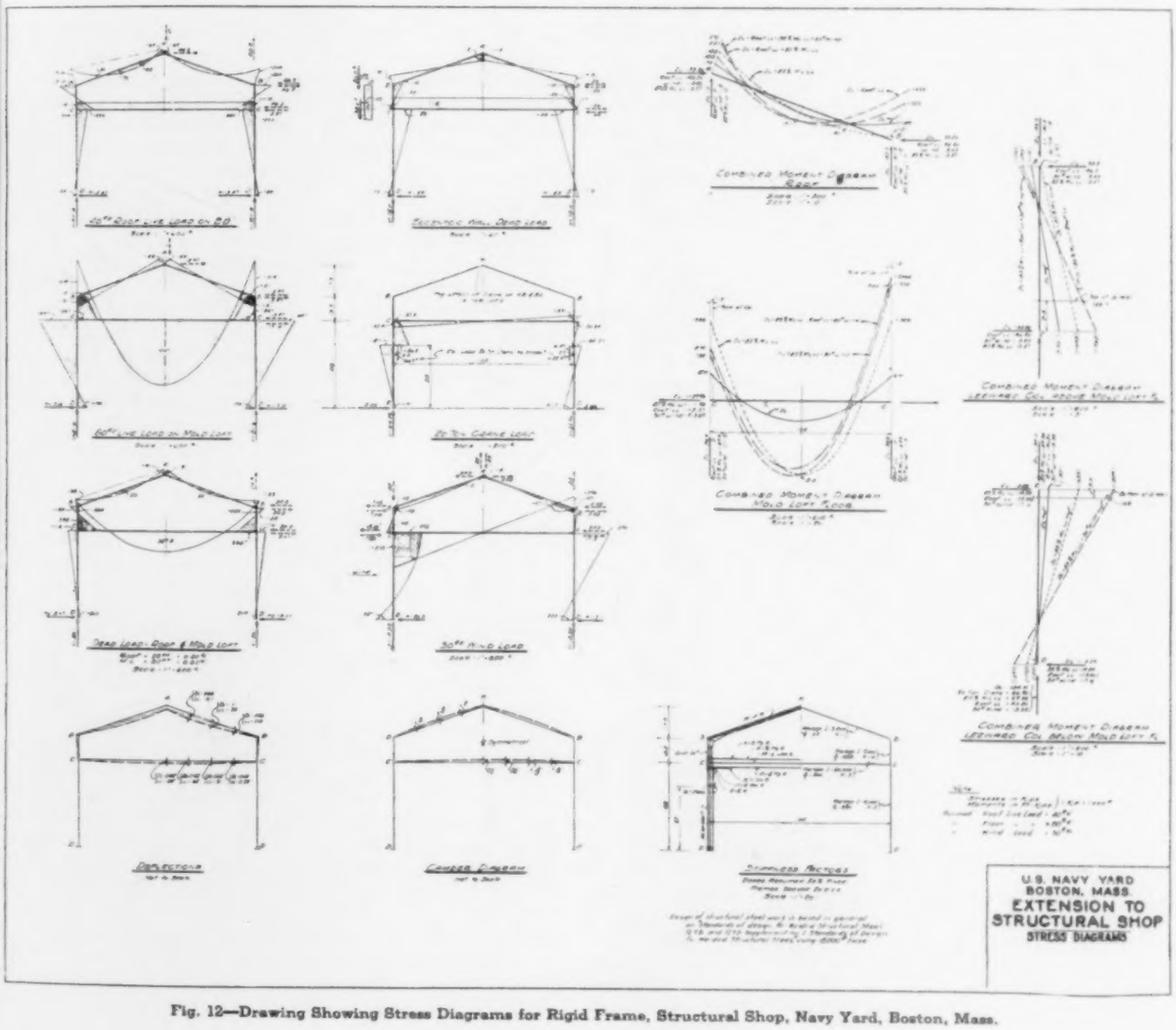


Fig. 12—Drawing Showing Stress Diagrams for Rigid Frame, Structural Shop, Navy Yard, Boston, Mass.

riveted joint does, is basically inefficient and uneconomical as compared with the welded joint, and will ultimately be displaced by it. Unfortunately this will involve the scrapping of hundreds of thousands of dollars worth of fabricating equipment adapted only to riveted work. Some tools such as shears, planers, bend brakes, bending rolls and press equipment are adapted for fabrication in connection with welding but most of the punches, spacing tables, drills, and riveting equipment with its numerous and costly accessories, must sooner or later be discarded, as must methods of handling based upon years of riveting experience. The not unnatural reluctance of structural fabricating shops to write off such valuable assets will no doubt delay the transition; and there are in any case many problems yet to be solved by the many interested agencies before welding can completely displace riveting.

NEEDS OF THE WELDING INDUSTRY

Standards for both the design and field inspection of welding are a definite need, and a prerequisite to general acceptance of welding in structural steel work. To enable it to adopt welding for important structures, the Bureau of Yards and Docks has prepared such standards which are in use on work under its cognizance.

While the almost universal use of the shielded arc or coated electrode has gone far to establish the dependability of welding and while visual inspection is generally accepted as a satisfactory method in structural work of determining the integrity of shop and field welds, there is need for a convenient, reliable and inexpensive non-destructive method for field testing of welds. Standards for the qualifications of welders and for materials and processes, while of the greatest importance in maintaining a high standard of workmanship, need to be simplified, and the costly requalification of welders for each new job eliminated. Welding designers are needed who are not only versed in the theory of design but who are also thoroughly acquainted with the welding art, and with shop and field practices. The development of such designers, while already proceeding obviously requires time. To a much greater degree than in riveted work is the economy and even the quality of work in the shop and field, dependent upon the character of the designs prepared in the drafting room. "Over design" and a striving for non-existent economies—for example, splicing girder flange plates of different thickness or making floor beams continuous over supports—should be avoided. Conversely, details should be carefully designed so that punching or drilling of the heavier and longer members is avoided, with necessity for handling only the smaller connections for fabrication. The designer can likewise cooperate with shop and field personnel, with mutual benefit in working out welding procedures and sequences. By reducing the amount of field welding, by positioning in the flat or horizontal positions, and by providing convenient erection connections, the designer can effect substantial economies in field erection. Standard tables of connections and other details such as are available for riveted work, need to be developed for welded design, in order to reduce engineering costs and excessive time required to prepare welded designs. Fabricating shops can advantageously direct their efforts to reduction of fabricating costs, because welding—except where adopted for other than cost reasons—will be used only to the extent that it offers the more economical method of construction. Obsolete fabricating equipment and handling methods must be discarded and more liberal use made of clamping devices and jigs in the important work of assembly and of positioning equipment or manipulators to increase shop output. Greater use of large size high speed electrodes for flat and horizontal fillet welds will speed up work and reduce costs. The use of automatic welding equipment will, also in some cases, result in reduced costs. Two of the outstanding objectionable features in welded structural work which will eventually be overcome, are the overrun and irregularities in rolled steel sections. Steel manufacturers can contribute materially to the advancement of welding by accepting reductions in mill tolerances; and also by cooperating in the development of new rolled sections especially adapted to welding. Many shapes now used are obtained by cutting rolled sections or are built up from plates.

Fig. 13—Close-Up of Welding Cage and Welding Operation, 600-Foot Radio Towers, Naval Radio Station, Annapolis, Md.

The state of development of the welding industry today is due in no small part, to the indefatigable efforts of the welding equipment manufacturers and their sales forces. They can be relied upon to keep pace with technological advances, to develop and furnish needed materials and equipment, and to bring them to the attention of the industry. Schools and universities are playing a most important part in the advancement of the welding art by their research programs and more recently by establishing courses in welding and organizations such as the AMERICAN WELDING SOCIETY are performing a valuable service by disseminating data on new developments, and by enabling those interested in the development of the welding art and industry to meet and exchange their views and experiences.

Government agencies can assist in fostering the development of this important industry by identifying themselves with, and lending their influence to such development; and more especially by adopting welding and making available projects on which welding is specified.

There are of course many technical problems which are today only partially solved, but the real problem still confronting the welding industry is to obtain sufficient volume of welding work to enable the problems to be worked out. If the work be provided, the ingenuity of the research workers, the designers, fabricators, erectors, and equipment and steel companies can be relied upon to find the solutions. With their combined initiative, perseverance and thought all directed toward the same objective, the future of the welding industry can never be in doubt.

HARD-FACING BY FUSION WELDING*

By T. B. JEFFERSON, M.E.†

IN EVERY industrial field—construction, milling, mining, dredging, quarrying, textile manufacturing—in fact, wherever mechanical equipment is in use, efforts are being made to overcome or at least retard the effects of the destructive forces causing wear. The wear encountered in industrial operation may be classified in five distinct types. However, this presentation will consider only that wear resulting from abrasion and impact since the others are not a serious factor in cases of severe wear.

We have learned, through our daily pursuits, that the abrasive effects of paper upon a pencil may be reduced by the use of a harder pencil. In selecting a harder pencil it is possible to produce a finer line from a pencil point that will last much longer, i.e., a more abrasive resistant pencil point.

Engineers, in a similar manner, by increasing the hardness of the metallic parts subjected to wear, are endeavoring to reduce the effects of abrasion and the other agents destroying the machines of industry. This increase in hardness may be obtained by either of the two basic methods for hardening metals.

When uniform hardness throughout the part is desired it is usually manufactured from an alloy steel and heat treated. This, however, is an expensive process and is not necessary if the part is subjected only to surface wear. Surface hardness may be obtained in any one of a number of ways.

The most common means of surface hardening is case hardening or carburizing. A somewhat similar but more expensive process for surface hardening is nitriding. There are also a number of patented processes in which the items to be surface-hardened are heated to high temperatures and exposed to carburizing gases and controlled atmospheres of ammonia gas, hydro-cyanic acid gas and others. In each of these processes the temperature of treatment is varied according to the depth and characteristic of the case hardness desired and the kind of steel being treated. The final hardness is obtained by quenching in either oil or water; the method of quenching being likewise governed by the character of the hardness desired and the kind of steel being treated.

Induction heating and quenching, flame-hardening, metal spray and electro-plating are also used extensively to increase surface hardness. The advantage of these methods is that only a small per cent of the total weight of the part to be treated is heated to the high temperature necessary to obtain the required hardness.

Another process for surface hardening that is of particular interest involves the use of welding to apply a hard metal to the wearing surface of a softer metal, or as it is known today, hard-facing by fusion welding.

Hard-facing may be defined as a process of overlaying, by welding, a metal with high hardness characteristics on a metal of lesser hardness so that the surface of the softer base metal which is normally subjected to the greatest wear will assume the characteristics of the harder metal.

In general this process for surface hardening may be readily applied to all ferrous or ferrous alloy materials. As a rule, however, it is not recommended for the higher carbon (over 0.50% carbon) steels as the chances of breakage are too great. In hard-facing some of the higher carbon and higher alloy content steels it is usually necessary to preheat the parts to be treated and to heat treat them following the application of the hard-facing material.

The hard-facing materials of commercial manufacture which are available for general use may be classified in one of three groups:

(*a*) The Ferrous Alloy Group

This group is comprised of welding rods for hard-facing having an iron base and alloyed with chromium, manganese, molybdenum, nickel and silicon. This group may be more closely classified by subdividing it into: (1) Those alloys containing less than 20% alloys, and (2) those alloys containing more than 20% of the alloying elements. The hardness of the deposits of this group range from 414 Brinell to 653 Brinell.

(*b*) The Non-Ferrous Alloy Group

This group consists of welding rods for hard-facing which are alloys of chromium, tungsten, cobalt and molybdenum and sometimes contain small quantities of iron. The amounts of iron are so small as to have no effect upon the non-magnetic properties of the rod. The hardness of this group at room temperature is about the same as those of the ferrous alloy group. The non-ferrous alloys, however, tend to retain much of their hardness at high temperatures, giving this group a particular quality known as "red hardness."

(*c*) The Diamond Substitute Group

This group is so-called because the carbides of tungsten and tantalum and the borides of chromium comprising this type of material approach the diamond in hardness. They are among the hardest materials available to man and range between 8.5 and 9.5 on the Moh scale of hardness. Since this group cannot be applied by self-fusion but must be bonded to the base with some lower-melting alloy it is subdivided into two classifications: (1) The rod form in which the diamond substitute particles are inclosed in an alloy steel tube or uniformly distributed in a cast alloy rod; or (2) the insert or powdered forms.

Metallurgically, the deposits of the ferrous alloy rods may be either of a martensitic or an austenitic nature. Martensitic deposits exhibit their full hardness in their initial deposited state; that is, their hardness shows little or no increase upon cold working. The higher the hardness of a martensitic deposit the better is its ability to resist abrasive wear and deformation, and the less its resistance to impact. Austenitic de-

* Presented at Annual Meeting, A. W. S., Chicago, Oct. 23 to 27, 1939.
† Associate Mechanical Engineer, Marine Design Section, Office of Chief of Engineers, U. S. Army, Washington, D. C.

posits are generally called self-hardening. They differ from martensitic deposits in that they are relatively soft as deposited and have the property of hardening at the surface when deformation takes place in cold working. The rest of the deposit remains relatively soft; consequently an austenitic deposit is suitable for resisting impact wear.

Deposits of the non-ferrous alloy hard-facing materials obtain their maximum hardness in the "as-deposited" stand and are therefore of a martensitic nature.

The deposits of the diamond-substitute group differs distinctly from both of those previously mentioned in that they are of a matrix type. This group consists primarily of rods made up of sharp irregular shaped carbide or boride compounded particles uniformly distributed in a tough alloy binder; however, powder and insert forms are also used.

Some manufacturers mix the powdered particles with a paste so that a sudden blast from the blowpipe or arc will not blow the particles away before they become embedded in the base metal. In the case of the inserts the shaped diamond substitute particles are set in the wearing surface and welded in place. When using the powdered form the particles are merely scattered over the base metal. Then upon heating the base metal to a melting temperature the diamond substitute particles, because of their greater density, sink below the surface and embed themselves. Thus, when deposited, these particles, which are extremely martensitic, become firmly embedded in a strong alloy base metal of austenitic characteristics. In this manner the resultant deposit possesses the good qualities of these two types of metallurgical structures without their individual deficiencies.

When it is decided that a machine part is to be surface-hardened by a process other than welding considerable care is exercised to determine the proper procedure to use. However, if the decision is made to hard-face the part the price of the material rather than its metallurgical characteristics are not infrequently the deciding factor in the selection of the hard-facing material. The failure of the average user to consider the fundamental metallurgical characteristics of hard-facing materials is often the cause of many unsatisfactory hard-facing applications. Without considering the facts at hand, hard-facing materials are frequently applied because, "It is the cheapest," or, "Someone recommended it," or, "It was satisfactory when used on another application," even though there is no similarity between the two applications. The fallacy of such a practice may be seen readily and while it would not be expected to work for any of the surface-hardening processes it is nevertheless repeatedly tried in connection with hard-facing applications.

To date there has not been developed a standardized test for determining the wearing qualities or the abrasion resistance characteristics of materials nor has a satisfactory means of obtaining this property by comparison been established. There are, however, several known methods for readily obtaining the hardness of a material and for accurately comparing metals as to their hardness.

By the simplest test, for example, the abrasive effect of paper upon a pencil, it has been determined that the higher the hardness the greater the abrasive resistant character of the material. For this reason it is believed that hardness is probably the best criterion of wear resistance.

If the hardest possible deposit is desired, a material of the diamond substitute group should be selected. It should be remembered, however, that while materials of this group produce the hardest deposits they are also the most expensive. Price alone cannot be considered as an index to hardness and quality; this will be brought out later in this paper.

In selecting a hard-facing material for the best results on a particular application the following facts should be considered:

(*a*) Ferrous Alloy Materials

The materials of this group may be applied readily by either the oxyacetylene or the electric-arc welding processes. The electric-arc process will be the faster and the more economical, but because of the lower operating temperature of the oxyacetylene process better control of the deposit can be maintained. The lower temperature also means less penetration and consequently less dilution of the deposit by the base metal.

Those rods of this group producing martensitic deposits will usually have poor corrosion resistant characteristics. Their outstanding qualities are their ability to resist abrasion and deformation. When the uniformly hard surface of a martensitic deposit is subjected to impact it may wear very rapidly due to the brittleness of the surface which is liable to chipping under impact.

The austenitic deposits of rods of this group, because of their work-hardening qualities, are best for resisting impact wear. After their hardness has been increased by cold working they are also suitable for resisting abrasive action. Usually, because of their higher alloy content the ferrous materials producing austenitic deposits have good corrosion-resisting qualities.

(*b*) Non-Ferrous Alloy Materials

The materials of this group are best for producing thin and smooth deposits and deposits that are capable of resisting corrosion. The martensitic nature of the deposit of this group makes it highly abrasion resistant, a quality the deposit retains at high temperatures —"red hardness."

The non-ferrous alloy materials may be deposited by either the electric-arc or the oxyacetylene welding processes; the latter is usually preferred. Better control over the deposit may be maintained by the oxyacetylene process and there is also less loss of the higher priced hard-facing material.

(*c*) Diamond Substitute Group

The materials of this group which are in the rod form may be applied by either the electric-arc or the oxyacetylene process, with oxyacetylene the preferred method. The insert or powdered forms are usually "puddled" with the oxyacetylene flame.

Since the diamond substitute particles are deposited in a matrix of a softer material which is able to withstand shock the deposits of this group are generally suitable for withstanding impact as well as abrasion. By selecting a suitable binder material the deposits of the diamond substitute materials can be adopted for practically any type of service. The extreme hardness of this group is maintained quite well at a red heat.

In the application of any hard-facing material the most satisfactory results will be obtained if the melting point of the hard-facing material is slightly below that of the base metal and if the coefficient of expansion of the hard-facing material and the base metal are approximately the same. If these two conditions exist the hard-facing deposit will not be seriously diluted by the base metal nor will it be likely to crack or break loose when cooling.

Actual practice has proved that some of the less expensive rods, for example those in the ferrous alloy group producing an austenitic deposit, are far superior to some of the higher priced materials. This is particularly true

if the hard-facing deposit is to retard impact wear. In combating abrasive wear these cheaper austenitic materials are sometimes worn away before they have had an opportunity to work-harden to the point where the deposit can effectively resist this destructive force. However, a martensitic deposit with its high initial hardness is able to resist the scouring action of this abrasive force and as a result lasts indefinitely in this service.

A mistake commonly made by the average user is that of depositing the hard-facing material too thickly. Some are of the opinion that if a thin deposit is effective a thicker deposit will be more effective. In reality this is not always the case. It has been found that the thinnest application that will produce satisfactory results is the one to use. Rarely, if ever, should a hard-facing deposit be over $^1/_4$ inch in thickness. The usual practice is to apply the hard-facing material no thicker than it can be deposited in a single pass. When one layer of hard-facing is deposited over another the lack of elasticity of hard-facing materials usually produces a cracked and weakened surface. Such a surface condition usually decreases the effectiveness of the hard-facing. Also multiple layer deposits of hard-facing are softer than a single layer application. For example, in a recent test it was found that a single bead deposit of a ferrous alloy hard-facing material had a Brinell hardness of 590. When a second bead of the same material was applied over the first the Brinell hardness was reduced to 524, while 461 Brinell was the hardness of the surface of a triple bead deposit.

If the nature of the work is such as to require the rebuilding of a part to a height greater than that obtained by a single application of hard-facing, it will be found that a high carbon material deposited layer upon layer until the part is within $^3/_{16}$ inch of the desired height and then hard-faced it will provide a more satisfactory surface. Not only will the surface be stronger but it will also be harder. In the case of the previously mentioned ferrous alloy deposit with its Brinell hardness of 590, when applied over a high carbon deposit its Brinell hardness was increased to 653.

It is hoped that the fundamentals which have been presented has in a degree cleared away some of the mystery commonly associated with hard-facing by fusion welding and has given a clearer idea of what may be accomplished by hard-facing and what may be expected of this so-called "magic metal."

FLOW OF MATERIALS IN Production Welding*

By WALTER W. PETRY†

WELDING in its modern form and application is of such comparatively recent and extensive development that many organizations have seen their welding department in some out-of-the-way corner grow up to occupy what now becomes a congested and heavily-loaded manufacturing area. This is not intended to be an indictment against these shops, which by force were required to add on and add on, without having sufficient assurance of the future value of welded construction to warrant rearrangement, relayout and moving, but is intended to call attention to the advantages welding fabrication has over other forms of construction and to show how much greater would be the savings had the user of welding been able to look ahead and visualize the place welding should and would take in his production set-up.

In many cases the welding supervisor is not trained in both welding engineering and material flow. If he knows all about material flow, he may not have foresight into the future possibilities of welding. He will then only design the shop layout for the present conditions, which tomorrow may be out-of-date. If he knows welding and keeps abreast with the new developments, he may not have the knowledge necessary to make the proper layout for unimpeded flow of materials through his shop. Quite frequently the planning and development work of the weld shop is entirely in the hands of someone who has many other things on his mind and little time to plan carefully for the proper flow or sequence of operations on materials through the many necessary processes to make the net result, a good product at the right price and at the right time. It usually follows that a production weld shop is as properly laid out as the supervisor, superintendent or manager is flow-production minded.

By inefficiencies in a weld shop due to lack of knowledge of the best welding practices, best welding machinery, best welding materials and best layout for uninterrupted flow of materials, we sacrifice first, prompt delivery, which in many cases is the difference between landing and not landing a job, and second, profit, which is just and due any manufacturer. Price, quality and delivery, we will assume to be the most important factors upon which business is obtained. The following cases are chosen from a large number which came to my knowledge as being typical of the thoughts expressed above. The first becomes just a little difficult to describe due to the fact that the name of the product under consideration cannot be used here.

A GALVANIZED STEEL WELDED PRODUCT

It is a metal container roughly 8 inches wide, 20 inches long and 30 inches deep, the shell, or body, made

* Presented at Annual Meeting, A. W. S., Chicago, Oct. 23 to 27, 1939.
† Welding Consultant, The Cincinnati Milling Machine Co., Cincinnati, Ohio.

of mild steel 16 gage with flanged ends of 10 gage, manufactured in quantities of 25,000 or more. The flow of materials begins with first, the spotting of the car, convenient to shear; second, handling sheets in packs instead of single sheets; third, conveyed by truck, and sheared to size while unloading; fourth, stocked in proper sizes adjacent to presses. The press operation, of course, makes the product too bulky to store, which means the forming process should be timed with production requirements.

The original process was laid out so that operators were stationed at points equally spaced with room enough to roll the tank on a bench for positioning each edge of the rectangular shaped tank. This caused four changes of position for each end, or eight positions for each tank. It will be noticed that the economy of floor space obtained by eliminating this rolling procedure would not be conserved when using gas torches due to the fact that heat and gases from the torch required ample spacing for ventilation.

The point I wish to make here is that a lack of knowledge led to the selection of the wrong process. The fact that the tank had to be dip-galvanized after welding caused this mistake because acetylene welds can be quickly pickled preparatory to galvanizing and electric arc welds made with coated electrodes cannot be cleaned by the pickling process. Cleaning of the slag from an electric weld on this metal made the manufacturing cost prohibitive when using coated electrodes. It is true that with some rods the slag will spald off clean when properly welded under ideal conditions, but in practice there is just enough insoluble slags bonded firmly to the parent metal to make an imperfect galvanized job unless, as stated above, a prohibitive amount of labor is put on cleaning.

On the original set-up, ten welders produced 250 units per eight-hour day, and two men were required to handle by hand all material going to the welders and carry the finished units to the test racks. These welders occupied a floor space of 1200 square feet. On the re-layout, five welders and one assembler produced the same quantity and were more compact, occupying only 40 sq. ft. each, a total of 240 sq. ft. A simple gravity-roller conveyor carried the units direct to the test racks. The key to this improved set-up lay in the knowledge of the behavior of bare electrodes on thin sheet metal and speeds obtainable by that process. True, it was more difficult to get welders capable of doing a first-class job, but the finished product was so much superior and the floor space gained so valuable that the advantages tremendously offset the disadvantages.

VITREOUS ENAMELED WELDED PRODUCT

The next case illustrates a combination of process change and material flow correction. Several attempts had been made to use conveyors advantageously but these had only caused the set-up to become more clumsy and spread out. Each welder performed his own set-up, consisting of clamping the top of a refrigerator liner and the shell or sides into a jig for welding, followed by welding the three seams, which constituted the joint of the top to the sides and back. He then removed the product from the jig and passed it to the next welder whose operation was nearly the same jigging, welding in the bottom and removing from jig. These jigs were mounted rigidly on a building column, two to each column with an extra column installed between those regularly spaced 20 feet on centers; thus, to have all the jigs mounted required spreading out over ten bays of the building. Each column had to be a welding station with gas and oxygen piped to it.

After careful study, it was recommended to change the entire set-up by mounting the jigs on a special conveyor, which would have the proper speed and control for welding either by semi-automatic acetylene, or electric resistance process.

The special conveyor consisted of a mounting, which would index to position for loading welding and unloading, so that operators stationed by the material-receiving point loaded the jigs, threw controls, which carried it to the welders, who welded as it passed with only a few seconds lapsing between welds. The welders remained comfortably seated in chairs with arm rests adjustable to their desired heights. With welding concentrated in one place, it was a simple matter to arrange ventilation for the removal of the products of combustion and heat. In this manner, physical fatigue was reduced to minimum.

Previously 20 stations had been required to produce 2000 units per day using 20 men on each of two shifts. The revised set-up had capacity of 2000 units per day using 8 men on each of two shifts and condensed into one-half the floor space.

The trained production engineer might go to the very limits of production organization, yet fail to realize that the fundamental process may soon become obsolete, as did boiler manufacturers in their well-equipped shops for riveting, only to have welding replace this process before a good start had been made with the riveting machinery.

LARGE DIAMETER WATER PIPE

Realizing the need for production of steel water pipe more than a decade ago, a small welding company equipped itself for production of welded pipe in competition with riveted and mechanically-made seams, all of which were in competition with cast-iron pipe. Orders began coming in because of the savings made on fittings, turns, and the reliability of steel over cast iron in the larger diameters from 42 inches in diameter up to 84 inches. It soon became apparent that enlargement of the factory facilities was necessary. With much concern about the future, inquiry was made of all leading welding and forming apparatus manufacturers as to their very best and most modernized method for doing this sort of work. The manufacturers gladly responded and gave valuable suggestions. With that kind of information at hand, a carefully planned operation chart was made, showing each operation in detail. This chart dictated the location of machines rather than some one individual's idea of ideal arrangement, accessibility to power, or any of the other many arguments that so frequently disturb the plans of an engineer.

CONCLUSION

I have sighted these foregoing examples of outstanding blunders and their correction merely to illustrate the point that too frequently development goes forward with insufficient knowledge to allow a clear vision of the future possibilities of welding. In many cases this knowledge may be in the possession of a single engineer, highly trained and experienced in a special line of work, but more often the thorough job is done by the cooperation of a number of engineers working hand in hand many hours and delving into the depths of laboratory research to get the answer to the question—What is the right way to solve this problem?

WELDING METALLURGY

By O. H. HENRY* and G. E. CLAUSSEN†

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. To be published serially in the Welding Journal. Available in Pamphlet Form—47 pages Journal Size. Copiously Illustrated at $1.00 per copy. Special Prices quantity lots ten or more.

Editorial Note: The purpose of this series of lectures, FUNDAMENTALS OF WELDING METALLURGY, is to familiarize members of the welding industry with the composition and structures of the metals that are used, to show the effect of varied conditions of heat and stress in welding, to explain heat treatment and to illustrate how the knowledge of metallurgy can be used to control the welding process.

All lectures were prepared by Professor Otto H. Henry and Dr. G. E. Claussen. These men have been selected because of their exceptional ability in this field. Professor Henry graduated in 1919 with degree of B.S. in Mechanical Engineering from West Virginia University. Since then has secured professional degree of Mechanical Engineer from West Virginia University and Master's degree in Mechanical Engineering from Polytechnic Institute of Brooklyn. Before coming to Polytechnic, Professor Henry served as Instructor in Steam and Experimental Engineering at West Virginia University and in the Vocational Training Corps during the World War. Since coming to Polytechnic, Professor Henry has been in charge of courses in metallurgy and materials testing, and has served as commercial consultant of several firms. He is now Associate Professor of Metallurgical Engineering and is in charge of the New Degree Course in Metallurgical Engineering. He has been a member of several technical committees of the American Welding Society. Dr. G. E. Claussen received degree of Mechanical Engineer from Polytechnic Institute of Brooklyn, degree of Master of Science from Massachusetts Institute of Technology, and degree of Ph.D. from University of Sheffield, 1935. Instructor in Mechanical Engineering at Polytechnic Institute of Brooklyn 1931–1933. Research Assistant of Welding Research Committee since 1936.

Dr. Claussen is Secretary of the Fundamental Research Division of the Welding Research Committee and is well-known throughout the world as one of the co-authors of the critical digests of welding literature which appear regularly in the Welding Research Supplement.

INTRODUCTION

OF ALL branches of engineering, metallurgy is the closest to welding. "Welding Metallurgy" is intended to familiarize members of the welding industries, including fabricators and designers, with the composition and structure of the steel they use, to show how the steel is affected by the varied conditions of heat and stress in welding, to explain the mysteries of heat treatment, and to point out the way in which metallurgy can be used to control the welding process. No prior instruction in metallurgy is assumed in the following chapters, nor is a detailed acquaintance with welding technique required.

There is no pretense that all the metallurgical aspects of welding are dealt with, for example, corrosion and stresses. Emphasis is placed on fusion welding for the reason that practically nothing is known about the fusion question in resistance welding. Furthermore, the metallurgical principles of the heat-affected zone are basically the same in all types of welding.

General principles are emphasized throughout, in the belief that a few general principles replace vast numbers of particular facts. The endeavor has been to simplify everything as much as possible without distortion of facts or sacrifice of completeness. There are no formulas to be memorized. Instead, welding metallurgy deals with the structure, properties, and composition of the welded materials from which may be deduced the cycle of events which brought them about, or vice versa. The numerical information that is supplied often is approximate for the sake of simplicity.

WELDING METALLURGY

A large part of metallurgy is based on the change in properties of metals as they are heated. The essential part of commercial welding processes is the heating of a metal close to or above the melting point. Consequently, metallurgy is an important adjunct to welding. By means of metallurgy, we relate the temperature changes during welding to changes in the structure and properties of the joint.

* Associate Professor of Metallurgical Engineering, Polytechnic Institute of Brooklyn.
† Research Assistant, Welding Research Committee, and Adjunct Professor of Metallurgy, Polytechnic Institute of Brooklyn.

Part I—Temperature Changes During Welding

The important facts that we must gain about the temperature changes during the welding of a given metal or alloy are:

1. Rate of cooling
2. Maximum temperature
3. Length of time the maximum temperature is maintained
4. Rate of heating.

With these facts, we consult the principles of metallurgy to determine the effect of welding on the metal.

In gas welding (temperature of neutral oxyacetylene flame = 3200° C.) the rate of heating is slower than in arc welding, the molten metal probably attains a lower temperature, but the metal is usually molten a longer period of time than in arc welding (temperature of iron arc = 6000° C.). As a result, the rate of cooling from gas welding is slower than from arc welding, and adjacent base metal is heated over a larger area. In both processes the source of heat—arc or torch—moves at the speed of welding, say 6 inches per minute. The metallurgical effects depend upon maximum temperature, which is usually about the melting point of the metal, and size of heat source.

The size of heat source in gas welding varies directly as the acetylene consumption, and in arc welding as the current, the arc voltage being about the same for most electrodes of a given metal. During each inch of welding the heat delivered to the base metal is

$$\frac{\text{size of heat source (B. t. u. per minute)}}{\text{welding speed (inches per minute)}}$$

For a given thickness of metal the two factors vary as shown in Table 1.

Table 1

Type of Welding	Relative Size of Heat Source	Relative Welding Speed
Gas welding	Large	Small
Arc welding	Small	Large
Atomic hydrogen welding	Medium	Medium
Resistance seam welding	Large	Very large

Extremely rapid cooling occurs after the arc has been drawn for a second or two on a thick plate and then extinguished. If a large pool of molten metal is formed under the arc or torch, the rate of cooling is less rapid. The rate of cooling is most rapid in the weld. It is important to remember that the time required to cool 1 degree depends on the temperature of the metal under consideration and on many other factors. In general, the higher the temperature of the metal, the faster it cools, provided the source of welding heat has passed by. For example, when the weld metal is at 1400° C., it may be cooling at the rate of 500° C. per second, whereas by the time the metal has cooled to 700° C. the cooling rate may be only 50° C. per second, and at 350° C. only 5° C. per second.

Effect of Welding Variables

Number of Layers

If, instead of welding in a single pass, a multiple-pass weld is made with the same torch or electrode, the welding speed increases correspondingly, which reduces the heat delivered to the base metal during each bead, increases the rate of heating and cooling, and reduces the time the weld metal remains in the molten state. Should a different size of torch or different current setting be adopted in switching to multiple-layer welding, these changes must be taken into account.

Plate Thickness

The temperature changes during welding are affected in two ways by the thickness of the parts to be welded. If the same size of heat source and the same welding speed are used on thick as on thin plates, the temperature changes during the deposition of each bead will be more rapid in the thick plate, because the weld metal is surrounded by a greater mass of cool metal, which generally has about a thousand times better conduction for heat than air. Air thus acts as an insulating blanket around welding operations, which tends to increase the speed of welding operations.

If, as is usually the case, the size of the heat source is increased in changing from the thin to the thick plate, then the temperature changes during welding may be more or less rapid in the thick plate than in the thin, depending on circumstances.

Backing

If the plates to be welded rest on refractory material of low heat conductivity, such as fire-bricks, instead of on other metal plates, the rate of cooling after welding is decreased.

Preheating

Preheating decreases the rate of cooling after welding and sometimes removes the metal from a zone of low temperatures in which it may be brittle and liable to cracking. The second advantage of preheating will be discussed in a later chapter. Preheating may be accomplished in a variety of ways, such as by separate flame, by welding in a furnace, or by depositing successive beads before the preceding beads have cooled completely.

Questions and Problems

1. Distinguish between heat and temperature.
2. Why does heat flow from the weld into the parts being welded?
3. In welding steel by the gas, arc and flash welding processes, the weld zone reaches at least 1500° C. It may cool to 500° C. in 1 minute, 30 seconds, and 5 seconds, respectively, for the three processes. What is the average rate of cooling, neglecting the small evolution of heat on freezing?
4. If a gas weld is made in $^1/_2$-inch plate, will the center of the weld (mid-thickness) cool more rapidly than the surface?
5. A welder observes bands of colors adjacent to his welds in cold-rolled sheets. What is their significance? (Cold-rolled steel is free from mill scale. The oxide film on steel increases in thickness as the temperature is raised. Films of oxide formed above about 200° C. produce interference colors.)
6. Why does preheating decrease the rate of cooling after welding? (Suppose the metal were preheated almost to the melting point.)

Welding Society ACTIVITIES — Related Events

MESSAGE FROM OUR PRESIDENT

A new year is in the making. There is every reason to believe that it will be a prosperous and beneficial year for the AMERICAN WELDING SOCIETY and we trust that it will also be a happy one for all those connected with the welding industry. The Society has undertaken a very ambitious program of development and growth which has been described in the Year Book recently published. At the time this message is written we are practically four thousand strong. We have active Sections in some forty industrial centers. THE WELDING JOURNAL is recognized the world over as the leading scientific publication.

George Terry Horton

The Welding Research Committee through its publication, the Welding Research Supplement, has established itself on a sound foundation throughout the world. Technical activities have grown apace and we are meeting the needs of the welding industry in the matter of codes and standards.

With all these accomplishments it would be comparatively easy to make the fatal error of becoming self-complacent. After all, the AMERICAN WELDING SOCIETY is a mechanism for cooperation and mutual understanding. No matter how efficient are the staff, elected officers and appointed committees, actual accomplishments are determined by the amount and kind of cooperation given by the membership at large.

The membership has grown so that the personal contact possible in the early days of the SOCIETY is no longer feasible. This deficiency can be overcome somewhat by visitations to the various outlying Sections, but it can be done more effectively if every member of the SOCIETY will become a member of the great team and take an active part in the affairs of the SOCIETY. If you are willing to prepare a paper for presentation before a local Section or a national meeting or for publication in the JOURNAL, please notify your local Section and national headquarters. If you are able and willing to serve on one or more of our important technical committees, make your wishes and talents known. Perhaps your ideas run along the lines of sales. If so, there is an opportunity to become a member of the local or national Membership Committee or to cooperate with the local Ways and Means Committee. These ideas are merely suggestive. Other methods and opportunities can be made equally as good. The point is that the AMERICAN WELDING SOCIETY is our Society and, therefore, our activities should be more than the mere payment of dues.

GEORGE T. HORTON, *President*

OBITUARY

Philip George Lang, Jr.

Philip George Lang, Jr., bridge engineer for the Baltimore and Ohio Railroad system for the last eighteen years, died December 9th, at his home, 117 Taplow Road, Baltimore, Md. He was 56 years old.

Mr. Lang had been ill for about three months. With him when he died were his wife, the former Eugenie Marie LeFort, and his only child, Miss Eugenie LeFort Lang, of Baltimore.

Mr. Lang was born in Philadelphia, Pa., September 24, 1883, the son of Philip G. and Marie Louise (Beck) Lang. He received his early education in the public schools of Philadelphia. He next attended Northeast Manual Training High School, Philadelphia, winning a four-year scholarship at the University of Pennsylvania, from which institution he graduated in June 1905 with the degree of bachelor of science in civil engineering. In 1922 Mr. Lang was awarded the degree of civil engineer by the university.

During vacations he was employed as draftsman with the Bell Telephone Company, Philadelphia, and as surveyor with the Pennsylvania State Highway Commission.

His first regular position was as draftsman at the Pencoyd, Pa. Works of the American Bridge Company, next entering railroad service in March 1906 as bridge designer with the Carolina, Clinchfield and Ohio Railroad, at Johnson City, Tenn.

P. G. Lang, Jr.

Mr. Lang's first position with the Baltimore and Ohio was in December 1907 as assistant engineer. He was promoted to chief bridge draftsman, May 1, 1917, and assistant engineer of bridges, August 1, 1918. On May 1, 1921, he was appointed engineer of bridges.

Projects which Mr. Lang supervised include the Allegheny River Bridge, Pittsburgh; Great Miami River Bridge, Lawrenceburg, Ind.; Little Kanawha River Bridge, Parkersburg, W. Va.; and Chicago River Bridge, Chicago.

Among the many articles and papers which Mr. Lang has written for technical bodies and professional periodicals are "Mechanical Trimmers Solve Ship-Loading Problem," "Fusion Welding of Bridges," and "Ninety-Four Years of Bridges at Harpers Ferry." At the 1930 session of the International Railway Congress in Madrid, Spain, he delivered a report for America on "Static and Dynamic Stresses in Railway Bridges."

Mr. Lang was a member of the Engineers' Club of Baltimore, and served as its president in 1937–1938. During the same period he was president of the AMERICAN WELDING SOCIETY. He was also an active member of the American Society of Civil Engineers, American Railway Engineering Association, American Standards Association and Association of American Railroads. As chairman of the AMERICAN WELDING SOCIETY's Committee on Bridges, he helped to formulate "Specifications for the Design, Construc-

tion, Alteration and Repair of Highway and Railway Bridges by Fusion Welding," which was published as a code by the SOCIETY in 1936 and has been endorsed by the American Railway Engineering Association and the American Association of State Highway Officials.

Mr. Lang was a Mason and a Shriner.

Funeral services were held at the First English Evangelical Lutheran Church, the Rev. Dr. Martin Luther Enders, pastor, officiating. Burial was in Druid Ridge Cemetery, Baltimore.

Mr. Lang took over the presidency of the AMERICAN WELDING SOCIETY at a very trying time in its history. While it was practically the unanimous opinion that the AMERICAN WELDING SOCIETY should be made a strong technical organization, the best procedure for so doing was the subject of considerable difference of opinion. The exact boundary of activities of the SOCIETY was also a matter of considerable concern. Largely through Mr. Lang's clear thinking, patience and fearlessness, the By-Laws of the SOCIETY were changed and methods of operation were established which insured the direction of travel of the SOCIETY in its goal to become the leading technical and scientific organization in the world on welding.

RAYMOND A. SPENCER SUCCUMBS FOLLOWING WEEK'S ILLNESS

Raymond A. Spencer, one of Windsor's industrial leaders over a period of a quarter of a century, died yesterday in Metropolitan General Hospital, following a week's illness. He was in his 55th year.

Held Several Posts

Associated with the Canadian Bridge Company for 27 years, Mr. Spencer was assistant general manager of that firm at the time of his death and held the same position with the Canadian Steel Corporation, the Essex Terminal Railway, Canadian Steel Lands Company and Canadian Steel and Wire Company.

During his years with the Canadian Bridge, Mr. Spencer travelled extensively throughout Canada and the United States and had friends all over the continent. He was particularly well-known in Windsor, taking an active part in activities of the Essex Golf and Country Club, the Detroit Boat Club, the Windsor Club, the Engineering Institute of Canada and the American Welding Society.

WELDING SCHOOLS

In connection with the work of the recently appointed Committee on Minimum Requirements for the Training of Welding Operators in Trade Schools, the SOCIETY headquarters is compiling a list of welding schools operating in the United States. In addition to needing this material for the Committee's use, the SOCIETY is constantly receiving requests for information of this kind from all parts of the country.

In order that the list may be made as complete and up to date as possible, it is requested that every welding school furnish SOCIETY headquarters with a brief statement of its operations. The information should include the name and address of the school and a statement of whether it is a public trade school, a private welding school or a training school operated in connection with an industrial concern. This information should be addressed to M. M. Kelly, Secretary, AMERICAN WELDING SOCIETY, 33 West 39th Street, New York, N. Y.

JOUBLANC JOINS LE TOURNEAU

Mr. J. C. Joublanc has joined the R. G. Le Tourneau, Inc., as Director of Metallurgy and Research. Mr. Joublanc was formerly connected with the metallurgical department of the Republic Steel Corp., for ten years, the research department of The Lincoln Electric Company for four years and for three years was chief metallurgist for the Harnischfeger Corp., as well as technical director of their Electrode Division.

OCTOBER JOURNAL

The AMERICAN WELDING SOCIETY still has a very limited supply of the October 1939 JOURNAL. Members desiring to do so can obtain extra copies as long as they last at 50¢ each. If you have some friend that you would like to receive a copy of this unusual issue, place your order at once.

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A NATION UNITED BY TELEPHONE

JUST twenty-five years ago, on January 25, 1915, the first transcontinental telephone call was made. East and West were united in dramatic ceremony.

President Wilson talked from the White House across the country, testifying to the nation's pride "that this vital cord should have been stretched across America as a sample of our energy and enterprise."

The inventor of the telephone, Alexander Graham Bell, in New York, repeated across the continent to San Francisco the first words ever heard over a telephone—"Mr. Watson, come here, I want you"—to the same Thomas A. Watson who had heard them in the garret workshop in Boston in 1876.

That ceremony ushered in transcontinental service twenty-five years ago. At that time it cost $20.70 to call San Francisco from New York. Now it costs $6.50 for a station-to-station call and only $4.25 after seven in the evening and all day Sunday.

In 1915 it took about half an hour, on the average, to make a connection. Now most calls are put through without hanging up.

These are measures of progress in the never-ending effort of the Bell System to give faster, clearer, more useful and courteous service to the people of the United States.

. . .

BELL TELEPHONE SYSTEM

RADIO CITY REMODELS SKATING RINK

The recent activity at the outdoor skating rink in Radio City's Sunken Plaza was caused by a decision to enlarge the rink and to install permanent rink piping. Heretofore, it has been a practice to lay

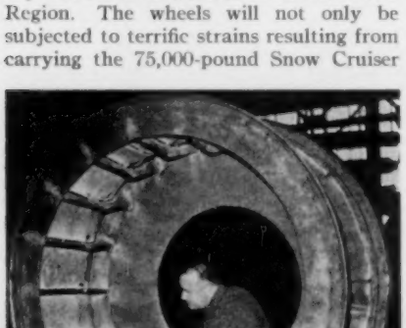
This Close-Up of the Welding Operation Shows Some of the Completed Welds, as Well as the Method of Welding Employed by the Operators. These Completed Welds Are Said to Be as Strong as the Pipe Base Metal Itself

pipe in the Fall and remove it in the Spring.

It would have been possible, of course, by merely laying a new foundation, to make a permanent installation out of the former piping system. However, in order to insure an absolutely leak-proof and corrosion-resistant installation, and to eliminate a mass of joints and the need for periodic tightening of these joints, the contractor, Almirall & Co., decided to join the pipes by oxyacetylene welding. With this new installation, also, it will be possible to lay a temporary Terazzo floor for summer restaurant service.

HOW SNOW CRUISER WHEELS WERE MADE

Design, selection of materials, and methods of fabrication of the 2000-pound wheels were major problems confronting the Research Foundation of Armour Institute of Technology when planning the Snow Cruiser which will be loaned to the United States Antarctic Service for survey and research work in the South Polar Region. The wheels will not only be subjected to terrific strains resulting from carrying the 75,000-pound Snow Cruiser over the trackless and uneven wastes surrounding the South Pole, but they must withstand high impact stresses at extremely low temperatures a condition which caused the failure of metal parts on mechanical equipment used during previous Antarctic explorations. Furthermore, it is highly essential that the weight of the wheels be as low as possible, consistent with necessary strength. Every pound of metal saved in the weight of the wheels reduces the power needed to move dead weight and adds to the useful carrying capacity of the Cruiser which is designed for a 5000-mile cruising range without contacting its base.



Dr. T. C. Poulter, Designer of the Antarctic Snow-Cruiser, Inspecting the Intricate Fabrication and Welding of Its Wheels Which Are Made of Inland Hi-Steel

General dimensions of each wheel are: diameter of outer and inner disks, 71 inches; diameter of drop-center rims, 66 inches; rim width, 30 1/2 inches outside and 28 inches inside; and, hub diameter, 20 inches. The weight of the two rims, the felloe and ribs of each wheel is 810 pounds. Almost 1000 pounds additional weight is added to each wheel by a cone-shaped hub, axle, gears, shafts and brake drums.

These dimensions and weights are impressive but still more impressive is the manner in which weight has been scaled down to the minimum by selection of the most advantageous type of steel. The 71-inch disks are made from 3/8-inch plates, the felloes are formed from 12-gage sheets, bracing ribs are made of 12-gage metal, brake drums are only 1/2 inch thick and the cone-shaped hub is made of 1/8-inch steel. These and other astonishingly light but strong sections are made possible by the use of Inland Hi-Steel which has as one of its main characteristics maximum resistance to repeated high impact shocks at extremely low temperatures—one of the most severe conditions which will be encountered day in and day out in the Antarctic Region.

The various parts of each wheel were ground preparatory to assembly. A bead casing support was then welded to the inside of each disk. The assembly operation was started by placing one disk on stools mounted on a heavy face plate. This disk was leveled by means of shims. The 12-gage felloe band was then placed in position and the other disk was lowered on top of the felloe band. Spacer blocks were used between the two disks to assure parallelism and correct spread. This assembly was tack welded and then chuck blocks fitted with adjusting set screws were used to assure accurate diameter. The wheel was then firmly secured to the face plate by four heavy clamps. All welding possible was completed with the assembly held rigid.

After removal from the jig eighteen 12-gage cross ribs were welded to the disks and the felloe band. Dimensions were the same after this operation except for a 1/4-inch uniform shrinkage of the tread of the wheel. All forming and welding stresses were relieved by normalizing.

A WRINKLE BENDING PIPE

A booklet describing the recently perfected wrinkle-bending method for bending pipe has been announced by The Linde Air Products Company, Unit of Union Carbide and Carbon Corporation. This process is finding wide application, particularly in the installation of cross-country pipe lines, or wherever else pipe must be "tailored" to fit. It depends upon the use of the oxyacetylene flame for heating a narrow band about halfway around the pipe at the point at which a change in direction is desired. When this band has reached a red heat the pipe is bent mechanically, with the heated portion at the inside of the bend. This causes a slight upsetting of the heated metal and produces a change of direction of from 4 to 6 degrees. When greater changes in direction are required, a series of wrinkle bends results in a smooth, long sweep bend of any desired angle. The upset metal projects outward from the inside of the bend, thus not interfering with the flow of fluid through the pipe and without restricting the diameter at the bend. The wrinkle-bending process is fully described in the booklet, together with suggestions for the mechanical bending of the pipe. Copies of this four-page, illustrated booklet, 8 1/2 x 11 inches in size, and entitled "Wrinkle Bending" are available from the nearest office of The Linde Air Products Company.

250-TON WELDED STEEL FLOOR FOR UNDERPASS

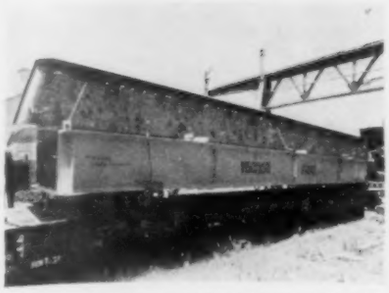
The steel work for the concrete roadway under the C. M. St. P. & P. R. R. at Wrightwood Ave. in Chicago is a 250-ton welded structure consisting mainly of parallel 36-inch, 240-lb. I-beams and 1/2-inch high tensile alloy steel plate.

Fig. 1—Welding Cover Plate to Bottom Flange of 36-Inch Beam

Since the tracks cross the street at an angle of 69° 50′, the structure is a skew shape; the street width is 48 feet, 8 inches and the beams are cut about 53 feet, 3 inches long. Length of the perpendicular between facia girder centers is 67 feet 1 inch. The beams are spaced on 2 feet 4 1/2 inch centers.

Shop fabrication consisted of assembling 5, 3, 2 and 1 beam sections. Deck plates were welded to the top flanges of the beams and 15 1/2 inch by 1 inch cover

Fig. 2—Beam Section Assemblies Were Welded Upside Down



Photos courtesy Air Reduction Sales Co.

Fig. 3—One of the 5-Beam Sections Loaded for Shipment, Weight, 45 Tons

plates 34 feet long were fillet welded along the sides of the bottom flanges, and further secured by $1^{11}/_{16}$ inches plug welds, 864 of these in all. Facia girders were built up of four $3^1/_2$ by 4 by $^5/_8$ inch angles and 30 by $^3/_8$ inch webs. Two thousand six hundred and eighty-five linear feet of welding were required in the shop fabrication of these sections, not including the plug welds.

Field welding necessary to complete the assembly amounted to 436 linear feet, about $12^1/_2$ per cent of the total amount of welding. The entire job was fabricated and installed by Wisconsin Bridge and Iron Company, of Milwaukee.

ACKNOWLEDGMENT

The author of the paper "Flash Welding Alloy Steel Tubes," which appeared in the June 1939 issue of WELDING JOURNAL, pages 372–373, informs us that the research upon which the paper was based was conducted in the welding shops of the Mannesmannroehren-Werke with the assistance of that company. The original article by Mr. Wilhelm Denker appeared in *Stahl und Eisen*, March 30, 1939.

MINE LOCOMOTIVE TIRES REBUILT

Mine 43 of the Peabody Coal Co. in Illinois has welded up 1376 worn mine locomotive tires with a breakage of only 11 units. Since the development of improved welding practices there has been no breakage whatever. This coal company, with mines situated throughout much of southern Illinois, has had many years of experience in repairing the tires. This experience has led to a method which apparently eliminates the uncertainty of results.

Several elements figure in the successful process. First, the worn-out tire is preheated. Then, during the welding procedure, a continuous motor-operated peening hammer is directed on the new bead while the wheel is slowly cooling in a heat-insulated case. Among the equipment used are arc-welding sets together with automatic heads, cables, reels, torch, peening unit and geared-down welding lathe.

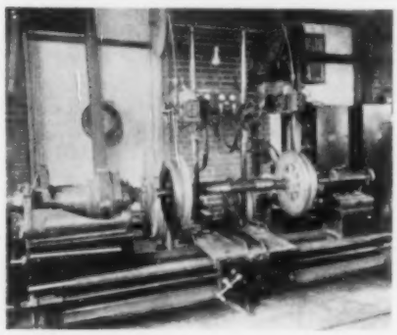


Photo courtesy General Electric Co.

Welder Building Up Tread and Flanges of Locomotive Wheels in the Repair Shop of Peabody Coal Co.

Since in most cases the deposited material is softer than the original tire, the repaired unit actually has more traction than it had when new. This, however, is dependent upon the type of electrode used. A hard surface may be put on if that seems preferable.

Officials of the Peabody Coal Co. have expressed satisfaction with the method. Since many varying factors are involved in determining the cost of such a repair job under different conditions, it is difficult to determine the exact expense per wheel. The figure of $11 per tire, however, has been given as the over-all cost for such a job.

WELDING PROBLEMS

"Welding Hints" is a new service recently inaugurated by the Harnischfeger Corporation of Milwaukee. This service is designed toward effecting savings of money and time—and maintaining machines, making emergency repairs, and replacing or rebuilding worn parts.

The "Welding Hints" consist of new and puzzling welding problems together with their solutions. They are printed on handy cards; and new additions to the series are made regularly. Each card handles a specific problem. Some of the problems dealt with are: the rebuilding of worn parts such as dipper teeth, side cutters, mining machinery, farm implements, etc.; building up of cutting tools; making of welded gears; rebuilding of sprocket teeth; welding of pipe structures; reclaiming of clutch pinions; and fast welding for poor fit joints.

This series should be particularly interesting for welding shops. However, various industrial plants also should find them of value from the maintenance angle. Further information can be obtained by writing the Harnischfeger Corporation, Welding Division, Milwaukee, Wisconsin.

WELDING AND CUTTING EQUIPMENT CATALOG

A 36-page, easy-to-use, pocket catalog describing one of the most complete lines of welding and cutting equipment in the industry is now available to interested persons.

This catalog not only describes up-to-the-minute equipment, but also contains recommended tip sizes for welding various metal thicknesses, complete data on tip sizes and gas pressures for cutting iron and steel from $^1/_{16}$ inch to 18 inches thick. These cutting data are complete as they include all fuel gases.

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BOUND VOLUMES WELDING JOURNAL

This is probably the last opportunity that any company library or general library will have to obtain a nearly complete set of bound volumes of THE WELDING JOURNAL. The following years are still available:

1929, 1930, 1931, 1932, 1933, 1934, 1935, 1936, 1937, 1938 and 1939

Price for the complete set—$46.75—plus shipping charges. Orders will be filled only as long as copies are available. The Society reserves the right to cancel this offer without further notice.

Single volumes may be obtained at $6.50 to non-members and $5.00 to members. Shipping charges additional. Each volume bound in attractive imitation black leather covers with Subject and Author Index.

WROUGHT IRON

The second edition of "Wrought Iron —Its Manufacture, Characteristics and Application," by James Aston and Edward B. Story, has been published by A. M. Byers Company of Pittsburgh as a source of up-to-date information on wrought iron. The new edition is the only up-to-date published work on wrought iron, its manufacturing processes, characteristics and fields of usefulness. The eight-page chapter on torch, arc, resistance and forge welding contains procedure tables and instructions. The handbook (97 pages, $1.00) is being distributed gratis to those requesting it on their business stationery.

REBUILDING DIES

A mid-west manufacturer was recently confronted with the necessity of either building two new dies to conform with an improved product design or revamp his existing dies. New dies would cost $2800 and would require eight weeks to build. To save this time and expense it was decided to rebuild the old dies, using an atomic hydrogen arc welder. The dies were completely rebuilt in three weeks at a cost of only $400—a saving of $2400 for the manufacturer.

The cost of rebuilding the dies included annealing the dies for welding, the welding operation, machining and normalizing to remove strains, recarburization to harden the metal, and polishing. Using atomic hydrogen welding for this type of work, metal of the same carbon content and chemical analysis as the die material can be added, and the shielding action of the hydrogen atmosphere prevents the formation of impurities during the welding operation. The build-up area showed the same grain structure and hardness as the rest of the die.

MALLORY DISTRICT MANAGER

W. M. Hayes, Detroit district manager of the Air Reduction Sales Company for the past thirteen years, joined the sales organization of P. R. Mallory & Co. Inc. on November 1st.

Mr. Hayes is widely known in the automotive and metal working industries through his activities in technical organizations as well as Detroit civic groups. He is a charter member of the Engineering Society of Detroit and has served on its affiliate council and various committees. He is also a member of the Society of Automotive Engineers and the AMERICAN WELDING SOCIETY, serving as an officer of the latter group for several years. He is also well known in Detroit yachting circles, and is recognized as one of the ablest sailors in the area, although of late he has leaned more toward power boats.

Mr. Hayes will concentrate his activities in the central west, and work directly from the plant at Indianapolis, Indiana.

WELDING TRAINING

Fusion welding has become increasingly important in the shipbuilding industry during recent years and has displaced the use of rivets in many new marine construction methods.

Consequently, in line with the Commerce Department's policy of keeping abreast of new developments that affect its work, a group of inspectors of the Bureau of Marine Inspection and Navigation met in Cleveland, Ohio, from December 4th to 11th, to undergo a brief and intensive study course in recent innovations of this rapidly developing science.

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The Bureau has set high standards in its welding code governing work done on merchant marine vessels, and qualification standards for personnel engaged in marine welding operations are equally stringent. Participation in courses of this nature is designed to keep the Bureau adequately staffed with experts capable of subjecting marine welding work to rigid inspection.

The group, headed by James W. Wilson, senior marine engineer of the Bureau, not only engaged in extensive discussions and studies but also visited several large plants in Cleveland and vicinity and observed the application of welding in actual operation. Leading welding authorities were highly enthusiastic regarding the benefits to be derived from such a program as were the participants themselves.

All phases of welding as applied to marine construction were studied, including flame cutting, gas welding, submerged melt electric welding, metallic arc welding, nondestructive tests of welds, stress relieving of welds, electric resistance butt welding and welding for both new construction and repairs.

X-RAY COURSE

Because of the increasing importance of X-ray procedures in testing materials in various branches of industry and art, New York University has scheduled three courses in industrial radiography as part of the science program of its Division of General Education, it was announced by Dean Ned H. Dearborn. Believed to be the first offerings of its kind in any university in this country, the new courses will begin February 1st. Herbert R. Isenburger, president of the St. John X-ray Services, will be in charge.

Designed primarily for engineers and others whose work involves the scientific testing of materials, the new courses will include both a series of fifteen evening lectures and an opportunity for those who desire laboratory work to familiarize themselves with actual practice in an industrial X-ray laboratory. In order to accommodate engineers from out of town provisions have been made to enable the laboratory work to be taken in thirty hours on five consecutive days.

The lecture course will comprise, in addition to a study of the various parts of an X-ray machine intended for metallurgical use, an explanation of the photographic procedure and a description of the use of X-ray in welding, in foundry practice, in various other industries and in the arts. The interpretation of exographs will be discussed as well as the principles and applications of gamma-ray techniques. Questions of cost will also be taken up in the lectures which will be illustrated by means of lantern slides taken from actual practice. Field trips to X-ray laboratories have also been scheduled.

Mr. Isenburger, who was born and educated in Germany, has been for many years associated with Dr. Ancel St. John, pioneer in the industrial use of X-rays.

LLEWELLYN RECEIVES HONORARY MEMBERSHIP CERTIFICATE

In a recent issue of the Journal we announced that the Board of Directors by unanimous vote had voted Mr. F. T. Llewellyn as an Honorary Member of the AMERICAN WELDING SOCIETY. This award was made in connection with his work in the development of engineering data for use in the design of welded structures which has assisted in the general acceptance of welding as a means of fabricating structural steel in building construction. The certificate was formally presented to Mr. Llewellyn on the evening of December 20th at a joint meeting of the New York Sections of the A. W. S. and A. S. C. E.

Preceding the award a dinner was given in Mr. Llewellyn's honor at the Engineers' Club. Some fifty members of the Society and friends of Mr. Llewellyn participated in the ceremonies.

The certificate was presented to Mr. Llewellyn by Dr. C. A. Adams, first President of the AMERICAN WELDING SOCIETY and the only other living Honorary Member of the Society. There follows some of the remarks by Dr. Adams.

"On an occasion of this kind it is customary to recite the notable achievements of the recipient of the honor to be awarded. Sometimes the achievements are spectacular; but you will not infrequently find that these spectacular achievements are, in part at least, matters of chance or of fortunate opportunity. Moreover, the degree of popular acclaim often varies tremendously with the nature of the achievement, apart from the real value of the services rendered. Again there is the question of motive. In some cases your admiration alone is aroused, whereas in others, the admiration, however great, is secondary to the deeper emotions of friendship and trust, developed by many years of loyal, faithful and effective service to his profession, to his friends, and to mankind; a quiet and unheralded, but continuously high-level service.

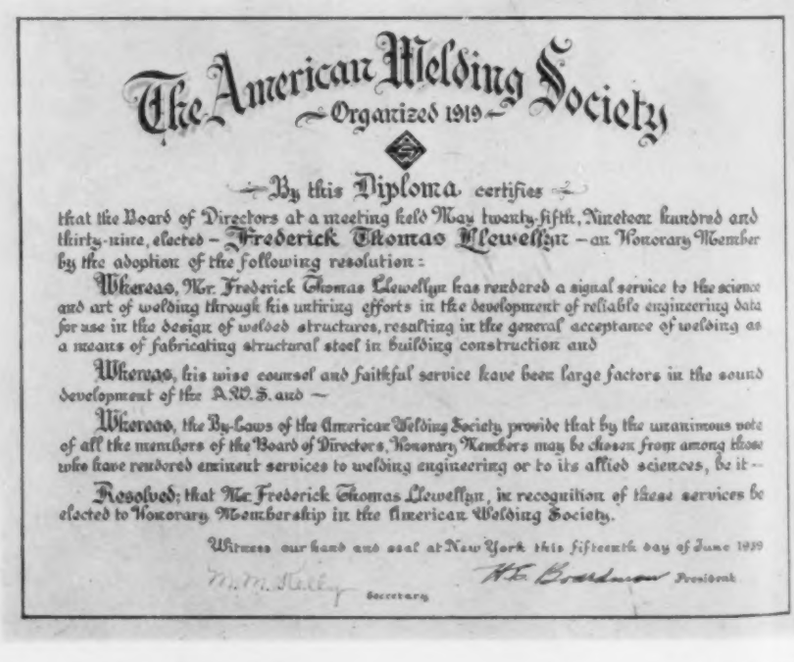
"The older one grows the more importance one attaches to this type of service and to the deep friendships that result therefrom. To most of us, these qualities come under the heading of character, and in looking over the world situation today, any thinking person must conclude that the only solution of the fundamental problems involved will be not through spectacular dictators, but through the level-headed, intelligent, fair-minded and faithful men such as our honored guest tonight.

"I have gone to him often for advice, and he has never failed me. He was not only fair, unbiased and without prejudice, but sound and wise. In some of the stormy days of Society affairs he was always calm and unperturbed, like a rock of refuge, in a storm.

"But I don't wish to leave the impression that he is always serious. In his quiet humorous way he was often the life of the party. I envy him his gift of reciting long poems from memory, and they are good.

"With this background, the mere recital of Mr. Llewellyn's professional record seems almost petty. However, some of the facts may be of interest.

"He was born June 1, 1869 in Wales and is a graduate of the University of London. He came to the United States in 1890 and began as a draftsman with a predecessor of the American Bridge Company. In 1894 he went to New Orleans to supervise the erection of the first steel skyscraper in that city, and stayed there for six years. In 1900 he went to Mexico to supervise steel work in Mexico City. Some time later, he worked with Carnegie Steel Company, and since 1919 to the date of his retirement on June 1, 1939, he had been associated with the United States Steel Corporation, latterly as Research Engineer. At retirement he had 49 years continuous service


The American Welding Society
Organized 1919

By this Diploma certifies

that the Board of Directors at a meeting held May twenty-fifth, Nineteen hundred and thirty-nine, elected – Frederick Thomas Llewellyn – an Honorary Member by the adoption of the following resolution:

Whereas, Mr. Frederick Thomas Llewellyn has rendered a signal service to the science and art of welding through his untiring efforts in the development of reliable engineering data for use in the design of welded structures, resulting in the general acceptance of welding as a means of fabricating structural steel in building construction and

Whereas, his wise counsel and faithful service have been large factors in the sound development of the A.W.S. and –

Whereas, the By-Laws of the American Welding Society provide that by the unanimous vote of all the members of the Board of Directors, Honorary Members may be chosen from among those who have rendered eminent services to welding engineering or to its allied sciences, be it –

Resolved, that Mr. Frederick Thomas Llewellyn, in recognition of these services be elected to Honorary Membership in the American Welding Society.

Witness our hand and seal at New York this fifteenth day of June 1939

M. M. Kelley Secretary

H. L. Boardman President

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"For many years he had been active in the affairs of the American Institute of Steel Construction. He was Chairman of its Committee which prepared the Specifications used in the design, fabrication, and erection of structural steel for buildings. As evidence of the high regard in which he was held by the Institute, he was presented, on his retirement, with an engrossed resolution of appreciation for his contributions to the structural steel fabricating industry.

"He worked on the development of wide parallel flange structural sections and cooperated in their national standardization.

"Since 1926 when he first became interested in welding, his efforts were largely devoted to promoting its orderly growth. In 1929 and 1930 he was President of the A. W. S. and later served on many technical committees, Board of Directors, Welding Handbook, Executive Committee, Welding Research Committee, Chairman of the Building Code Committee and many others.

"Some years ago there were three Honorary Members of the A.W.S. Dr. Elihu Thomson, the originator of electric resistance welding; Edmund Fouche, the originator of gas welding, and the speaker. The first two have passed on, so that I shall welcome Mr. Llewellyn into a very small fellowship which I hope, however, will grow more rapidly in the near future.

"Mr. Llewellyn, it is my pleasure and honor on behalf of the AMERICAN WELDING SOCIETY and its Board of Directors, to present you with honorary membership in this Society and to wish you many more years of happy service to your fellows and to your family."

WELDED CONSTRUCTION

"Welded Steel Construction," by Robert S. Hale, 170 pp. Published by the Pitman Publishing Corp., New York. Price $3.00.

Concise information on the advantages of welded steel construction in building work and on current practices in the application of welding to such operations is given in this small book. It is not a textbook on welding methods but rather a guide to the structural engineer or architect who wishes to gain knowledge of how welding can be applied to his structural problems. A considerable part of the book is given over to the application of welding to structural design, pointing out how welding construction varies from riveted work. Also included is valuable information on estimating structural steel costs, a brief description of methods of fabrication and erection and a section on the inspection of welded work. An appendix includes tables of standard sections, the portions of the New York and Chicago Building codes that relate to welding, and the AMERICAN WELDING SOCIETY'S specifications for highway and railway bridges by fusion welding.

Though the book itself is small it contains numerous references to fuller works on the various subjects covered.

WELDING IN TASMANIA

The illustrations shown below depict some welding applications in far-off Tasmania.

Fig. 1—Shows a Steam Shovel in Which the Teeth Have Been Welded. The Big Boom Was Riveted at First but Failed to Stand Up Under Service. It Was Repaired by Welding and Is Now Giving Excellent Service

Fig. 2—Shows a 17-Ton Foder Diesel Tray All-Welded

Photos courtesy of M. H. Beattie of Queenstown, Tasmania

ANNUAL MEETING

The next annual meeting of the AMERICAN WELDING SOCIETY will be held in Cleveland, Oct. 20–25, 1940.

HOLLUP DISTRIBUTOR

The Banks-Miller Supply Company of Huntington, West Virginia, has recently been appointed Hollup distributor for the Huntington territory. The Banks-Miller Supply Company is a well-known minemill, electrical supply and contractors' equipment house now carrying a complete line of Sureweld electrodes, Wanamaker Coated and Processed Electrodes.

WELDING GENERATOR

Dedicated to the "Man in the Helmet," the *Wilson Hornet* bulletin just published by Wilson Welder and Metals Company, New York, describes a revolutionary new electric arc-welding generator. This 18-page bulletin is profusely illustrated with photographs for clear-cut definition of operating and construction details of this essential piece of welding equipment.

A unique feature of this bulletin is its informal, straightforward analysis of the arc welder's problems, followed by a discussion of the way this analysis was applied to the design of the Wilson Hornet. Characteristics of the Hornet, given extended treatment in the booklet, include its exterior design, simple adjustment, self-contained exciter, locked polarity reversal, single-pole control and portability.

EMPLOYMENT SERVICE BULLETIN

POSITIONS VACANT

V-92. Manufacturer of complete line of bulldozers, trailbuilders and scrapers for "Caterpillar" tractors is in need of a very competent structural engineer for engineering department.

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Associate Inspector, Ordnance Material, $2000 a year.

Assistant Inspector, Ordnance Material, $1800 a year.

Junior Inspector, Ordnance Material, $1620 a year.

The examination which closed in August 1939, failed to produce an adequate register to meet the anticipated needs of the service, and is now reannounced for the purpose of supplementing the registers established as a result thereof.

Applications will be considered and rated approximately as received until May 22, 1940, unless an eligible register sufficient to meet the needs of the service is obtained sooner, in which event due notice will be given.

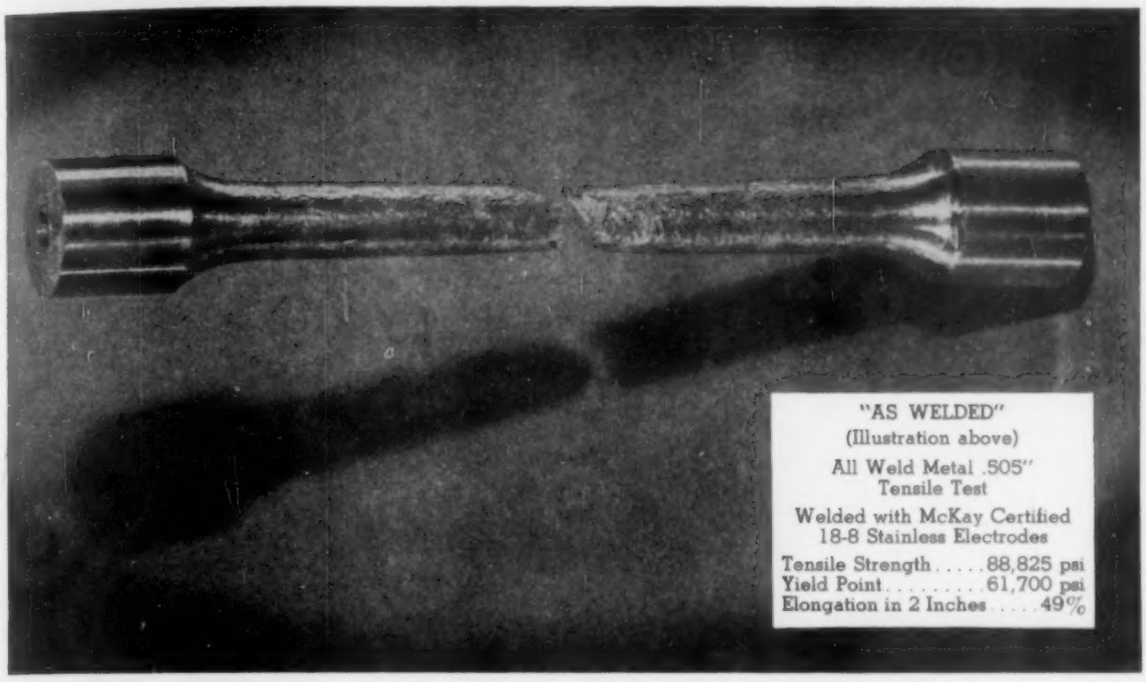
SERVICES AVAILABLE

A-306. Welder desires position. Extensive experience in Arc and Gas Welding, including job shop welding, all metals and alloys, automobile repair welding, barges, dredges, boilers, stacks and the like. Can furnish references.

A-330. Young man 25 years of age desires work as Electric Welder. 3 years' experience with a coal mining company in Pennsylvania. Single and willing to go anywhere.

A-331. Position wanted as Welding Control Engineer or Shop Superintendent. Age 30. Education college equivalent. 10 years' experience in boiler and pressure vessel fields. Physical, metallurgical, and radiographic laboratories and inspection. Production set-up, training and qualification of welders. Thoroughly familiar with A. S. M. E. and A. S. M. E.-A. P. I. Codes. Member A. W. S., A. S. M., A. S. M. E., A. S. T. M., and hold National Board Certificate.

A-332. Welding Engineer. 2 college degrees. Broad experience Arc and Gas Welding, brazing, cutting, layout welded constructions, supervising welding shop, repairs, physical welding tests, research and instruction. Aggressive man, seeks position in industry or school.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(Illustration above)
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3. **Spatter-free within practical limits.**
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NEW OFFICERS, GENERAL ELECTRIC CO.

Charles E. Wilson Elected President of General Electric Company, Philip D. Reed Chairman of Board—Gerard Swope Named Honorary President and Owen D. Young Honorary Chairman

Charles E. Wilson, executive vice-president, was elected president, and Philip D. Reed, assistant to the president, was elected chairman of the board of directors of the General Electric Company at the meeting of the directors of the Company in New York City, November 17th. They will take over their new responsibilities January 1st, succeeding Gerard Swope and Owen D. Young, who will become honorary president and honorary chairman of the board, respectively.

Charles E. Wilson Biography

Charles E. Wilson, who began his career in business as an office boy at the age of 13, has been executive vice-president of the General Electric Company since December 1937. It was a new position when he was appointed to it, after having been vice-president in charge of General Electric's appliance and merchandise department since 1930.

Charles E. Wilson

Mr. Wilson was born in New York City on November 18, 1886. He began working as an office boy in 1899 with Sprague Electric, a former constituent company of General Electric. Since then he has served in practically every function of the business and in many capacities.

He went from office boy to shipping clerk, factory accountant, production manager, and then assistant superintendent of the factory in 1914. Shortly after that he was appointed sales manager. In 1918, the year following transfer of the conduit business from Sprague to General Electric, he became assistant general superintendent of the Mazpeth, L. I., and New Kensington, Pa., works.

In 1923 he went to Bridgeport as managing engineer in charge of the conduit and wire business, and two years later he was appointed assistant manager of General Electric's Bridgeport works. Here began his intimate association with the appliance business, and in June 1928 he became assistant to the vice-president in charge of the merchandise department.

During this time Mr. Wilson devoted his principal efforts to the manufacturing problems of the department, and in 1930 was appointed manager of the merchandise department in charge of engineering, manufacturing and sales. In December of the same year he was elected a vice-president of General Electric, and was one of the original members of the newly formed appliance sales committee of the company. In 1935 he was assigned the additional responsibility of directing all appliance activities, including refrigerators, electric ranges and other kitchen appliances, as well as air-conditioning equipment.

Mr. Wilson is chairman of the board of the General Electric Contracts Corp.; a director of the General Electric Company and of the Monowatt Electric Corp., of Providence; Electric Vacuum Cleaner Co., of Cleveland, and of Houses, Inc. He is also a director of the Edison General Electric Appliance Co., Inc., of Chicago; Trumbull Electric Manufacturing Co., of Plainville, Conn., and the General Electric Supply Corp., New York.

Philip D. Reed Biography

Philip D. Reed, assistant to the president of the General Electric Company since December 1937, was born in Milwaukee, Wis., on November 16, 1899.

He joined the General Electric Company in its law department in 1926, one day before his twenty-seventh birthday. He holds degrees both in electrical engineering and law. He received his engineering degree from the University of Wisconsin in 1921 and his doctor of laws from Fordham University in 1924. He is a member of Tau Beta Pi, honorary engineering society.

Philip D. Reed

Mr. Reed's first job began while he was still a law school student, taking evening classes at Fordham, and in 1922, before his graduation, he became vice-president and patent counsel for the Van Heusen Products Company of New York. Before that he was patent solicitor for Pennie, Davis, Marvin & Edmonds of New York, and patent attorney for J. M. Van Heusen of Boston.

He entered the General Electric Company in 1926 as assistant to Vice-President C. W. Appleton of the company's law department in New York. In 1928 he was transferred to the incandescent lamp de-

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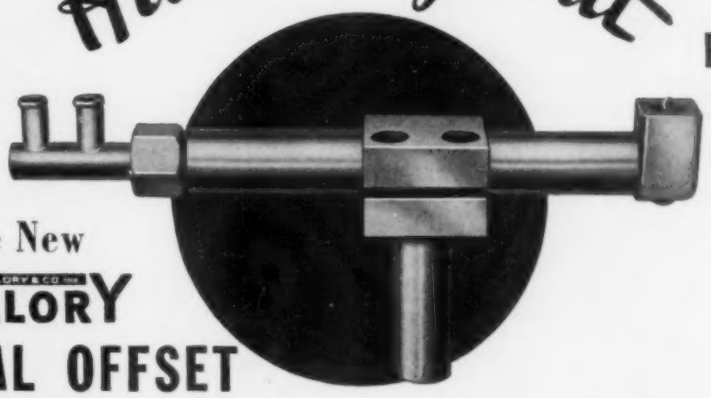
FOR SPOT WELDING IN *Hard to get at* PLACES . . . . . .



The New

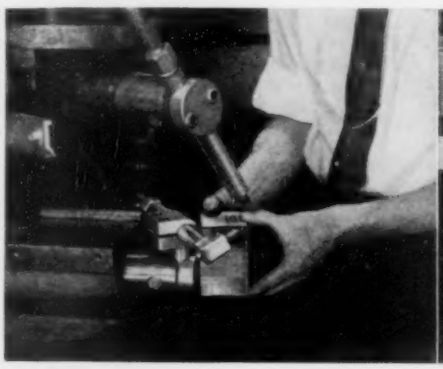
P. R. MALLORY & CO. Inc.

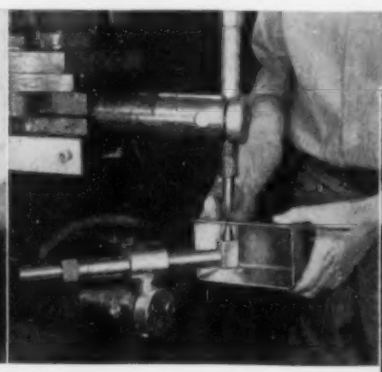
MALLORY UNIVERSAL OFFSET Water-Cooled Tip Holder

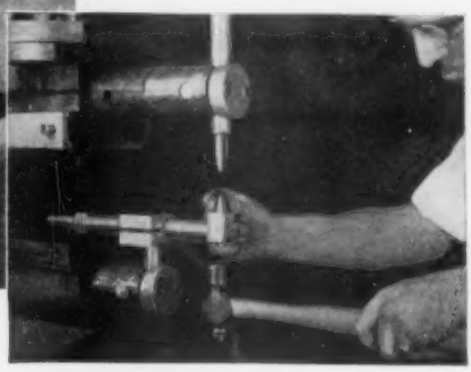
Here's a holder that has won the plaudits of large spot welding users as a major advancement in the resistance welding field. It has been engineered with the utmost care and constructed of materials especially selected for high strength, high conductivity and resistance to wear.

One of the best liked features of this Universal Offset Holder is the *Tip Knock-Out Device* which completely eliminates the difficulties often encountered in removing replaceable tapered shank tips.

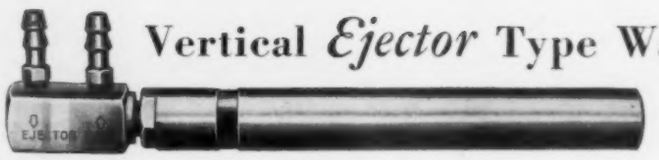
Write today for complete specifications and prices.







Vertical *Ejector* Type Water-Cooled Holders



Here's a time saver for every user of Tapered Shank Welding Tips. With these holders, tips are instantly removed by a light hammer blow on the hose-attachment end. It will not damage either the holder or tip.

Holders are furnished with standard barrel length of 8" and other lengths from a minimum of 4" (barrel length) are available on quotation.

P. R. MALLORY & CO., Inc.
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MALLORY

RESISTANCE WELDING ELECTRODES and HOLDERS

partment, and from July 1, 1934, until his appointment as assistant to the president in December 1937, he was general counsel for the lamp department.

Mr. Reed is a director of the Bankers Trust Company of New York, General Electric Company, the Locke Insulator Corp., General Electric Contracts Corp., Houses, Inc., Electrical Securities Corp., and the Federation Bank and Trust Company, of New York.

He is married and has two children, and lives in Larchmont, N. Y.

BUILDING INSPECTORS ATTEND WELDING CLASS

Fifty members of the Pittsburgh Bureau of Building Inspection and the Bureau of Tests of Allegheny County attended the opening session of an inspectors' course November 3rd at the East Pittsburgh works of the Westinghouse Electric & Manufacturing Co.

The city's new welding code permits welded construction for the first time, and inspectors of the two bureaus will spend one day each week for 8 weeks in the course to obtain a thorough grounding in the fundamentals of welding technique and inspection.

John J. Murray, divisional engineer of the Pittsburgh Bureau of Building Inspection, and W. W. Reddie, of the Westinghouse welding section, are directing the course jointly. According to Mr. Reddie, the Pittsburgh code is one of the most advanced in this country. Other cities have drafted welding provisions into their building codes, but in no other instance has the ordinance dealt specifically with welding; nor have the provisions been so nearly in keeping with modern welding practice as in the Pittsburgh code.

CHICAGO'S NEW STEEL RIVER TUNNEL TOWED INTO POSITION

Spectators lined the wall of Wacker Drive in Chicago when the huge double-steel tube for the State Street subway was anchored in the Chicago River, after being floated 15 miles through the lake from South Chicago. The tube will be sunk to its permanent position at the bottom of the river as soon as dredging operations on a 30-foot trench are completed.

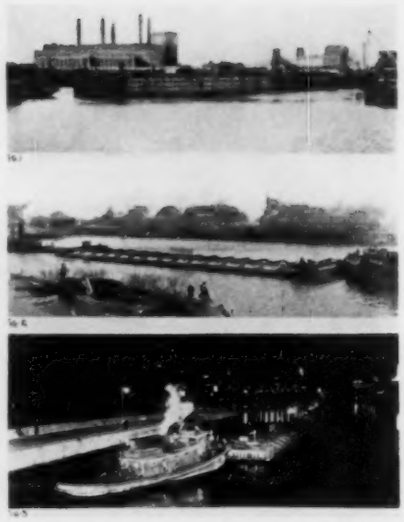

Photo courtesy Lincoln Electric Co., Cleveland

Double Tube, Concrete Covered, Arc-Welded Steel Tunnel Section for Chicago's New State Street Subway System

Fig. 1—The Tube as It Came out of Dry Dock with Concrete Partially Poured on Top

Fig. 2—The Top after Additional Concrete Poured on Its Top Had Sunk the Structure to Maximum Depth Permitted for Towing

Fig. 3—The Tube Being Towed through the Chicago River

Accompanying illustrations show the 200-foot structure as it came out of the dry dock (Fig. 1), after some of the concrete had been poured on top (Fig. 2), and as it was being towed in the Chicago River to be put into position for sinking (Fig. 3).

Chicago's new river tunnel is a double tube of concrete covered steel, 200 feet long, 40 feet wide and 23 feet high, weighing 6500 tons. It was made buoyant by sealing both ends. It is to carry State Street subway cars under the Chicago River.

Different from ordinary procedure in tunnel work, (which involves boring beneath the river bottom), sinking the section as a unit minimizes the earth covering over it—5 feet as against 15 with conventional practice. This feature provides a slighter grade in and out of the tube.

Built by Graver Tank and Manufacturing Co., of East Chicago, Indiana, the steel tube structure is arc welded throughout.

FUNDAMENTALS OF WELDING METALLURGY

How many times have you wanted to obtain a very brief textbook on the A B C of metallurgy which would enable you to understand articles on metallurgy and to appreciate the metallurgical problems involved in welding? Recognizing the need for material of this sort, the New York Section has sponsored a series of ten lectures to familiarize members of the welding industry with the composition and structures of the metals commonly used, to show the effect of varied conditions of heat and stress in welding, to explain heat treatment and to illustrate how the knowledge of metallurgy can be used to control the welding processes.

In order to make these lectures generally available, the SOCIETY will reproduce them serially starting with the January issue. A complete bulletin of 47 pages is also available for sale at a dollar per copy. Special prices can be arranged for quantity lots of 10 or more. These lectures have been prepared by Professor Otto H. Henry of Polytechnic Institute of Brooklyn and Dr. G. E. Claussen of the same university, who is also connected with the Welding Research Committee. Inasmuch as a limited supply is available, orders should be placed at once.

EMPLOYMENT SERVICE BULLETIN

With the upturn in business the AMERICAN WELDING SOCIETY performed a very useful function in placing good available men in suitable positions. The Society maintains this Employment Service Bulletin without charge. Members desiring to form new connections may have their advertisement inserted without charge and without indicating their names. The JOURNAL uses a box number in connection with each vacancy. Similar box numbers are given for Positions Vacant. We therefore believe that employers will also find it advantageous to announce their vacancies by box numbers in the JOURNAL.

REGO
WELDING AND CUTTING EQUIPMENT
- Welding Torches
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- *Standard in most welding rod coating.*
- *Thirty-five additional coating materials developed and tested in our laboratories.*
- *Technical data will be sent on request.*

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WATER TANKS

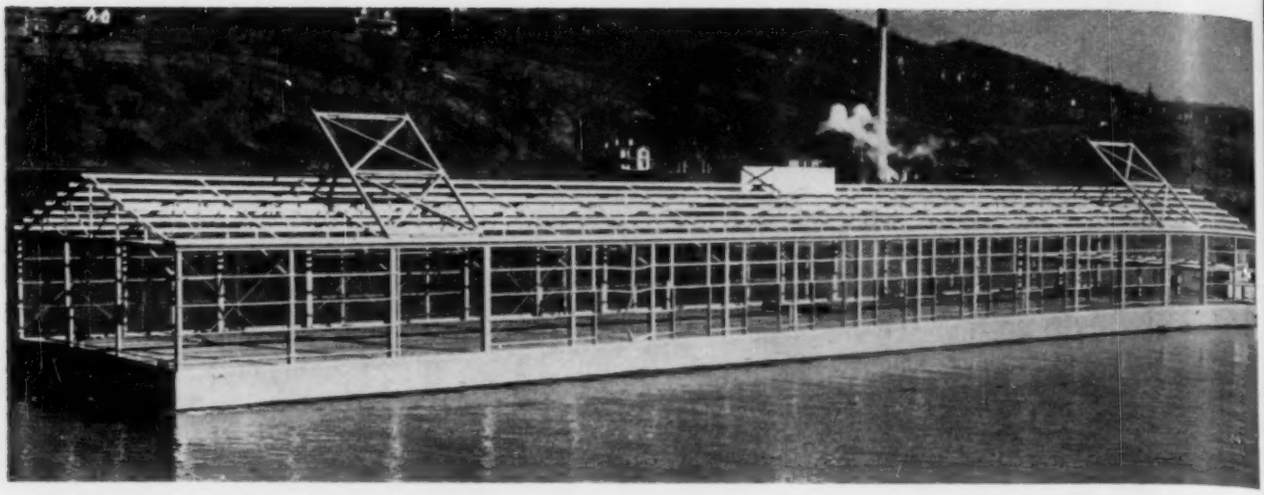
. . . . of welded construction

Elevated water tanks of modern design are built almost entirely of welded construction. They typify another example of a well established product, long used to provide gravity water pressure, that has—in this modern method of joining metal—been given greater efficiency, simplification of details and improved appearance.

CHICAGO BRIDGE & IRON COMPANY

Chicago	2455 Old Colony Bldg.	Birmingham	1507 North 50th Street	Philadelphia	1668-1700 Walnut St. Bldg.
New York	3398-165 Broadway Bldg.	Tulsa	1654 Hunt Bldg.	Boston	1565 Consolidated Gas Bldg.
Cleveland	2282 Rockefeller Bldg.	Houston	2919 Main Street	San Francisco	1097 Rialto Bldg.
Dallas	1489 Liberty Bank Bldg.	Detroit	1556 Lafayette Bldg.	Los Angeles	1455 Wm. Fox Bldg.

Fabricating plants in CHICAGO, BIRMINGHAM, and GREENVILLE, PA.



STEEL WHARFBOAT

A new welded steel wharfboat, for Greene Line Steamers, Inc., Louisville Terminal, was recently completed at Dravo Corporation's Neville Island Shipyards.

This structure is similar to the one recently placed in service at Cincinnati. The hull is 296′ x 57′ x 6′ and is believed to be the largest piece of welded equipment ever launched on the rivers.

To avoid wind resistance that would hamper this huge structure in its 603-mile journey to Louisville, Kentucky, the house sheeting was omitted. This will be put in place by the Greene Line Steamers, Inc., after the wharfboat reaches its destination.

With the completion of this structure, Greene Line Steamers, Inc., will have modern steel wharfboat equipment at all three of its terminal points: Cincinnati, Louisville and Huntington. This new boat, which has a much greater capacity than the wooden hull it is replacing, will probably handle 125 new automobiles a day in addition to the general cargo that is being transported between Cincinnati and Louisville by Greene Line Steamers, Inc.

PRECAST CONCRETE COVERED STEEL CYLINDER PIPE

Welding is playing a tremendously important part in the construction of a new pipe-line, the largest of its kind ever built, which eventually will carry 300,000,000 gallons of water daily to Boston's Metropolitan Water District. The art of welding makes this sturdy type of construction possible. Two sizes of pipe are being fabricated by welding, one section $12\frac{1}{2}$ feet in diameter and 12 feet long and the other $11\frac{1}{2}$ feet in diameter and 16 feet long. Steel cylinders and reinforcing assemblies weigh 45 to 50 tons when sheathed and lined with reinforced concrete. When completed in 1940 the new pressure aqueduct will be $17\frac{1}{2}$ miles long, connecting Wachusett Reservoir with a distributing point on the banks of the Charles River in greater Boston. Fabrication of steel cylinders and reinforcement assemblies for the pipe is being made by the American Concrete and Steel Pipe Company, under sub-contract to the Lock Joint Pipe Company, of Ampere, New Jersey.

In fabricating the steel sections, which are later covered with concrete, steel plates are tack-welded together to hold them in position for seam welding. To insure maximum strength of these seam welds a special plant has been developed to automatically weld all of these seams. Current for this automatic welding is being supplied by four 500-ampere transformer-type welding sets. The plates are then rolled to form a hollow cylinder and the final seam is welded. Bell and spigot rings are next welded in place and the section is then placed on a revolving mandrel and the reinforcing rings are welded on. Welding current for this work is supplied by motor generator arc welding equipment. The steel section, weighing from 5 to 10 tons, is then ready for concreting.

Approximately 7000 to 8000 feet, between 1.3 miles and 1.5 miles, of seam welds are made every day. This figure does not include the tack welding necessary to attach the reinforcement cages to the steel cylinder.

At the present rate of construction, 29 to 30 completed sections are turned out per day. Every 30 minutes one of these fabricated steel cylinders and reinforcement assemblies is taken out of the American Concrete & Steel Pipe Company plant. Each completed cylinder with joint rings welded to it is shop tested hydraulically for strength and water tightness.

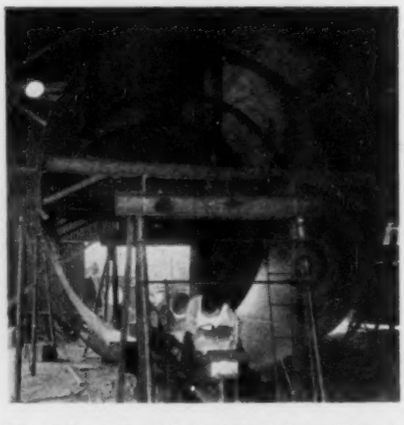
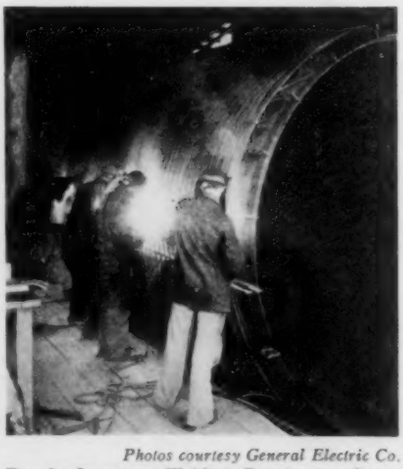


Fig. 1—Operators Making Final Seam Weld in Rolled Plates



Photos courtesy General Electric Co.

Fig. 2—Operators Welding Reinforcing Rings to Steel Cylinder Section

PRESIDENT, NORTHWESTERN UNIVERSITY

The Trustees of Northwestern University have recently announced the Inauguration of Franklyn Bliss Snyder as President of the University, effective November 15th.

WELDING WIRE BOOKLET

The tentative specifications for iron and steel arc-welding electrodes being considered by both the AMERICAN WELDING SOCIETY and the American Society for Testing Materials are offered, along with other useful material, in a 24-page catalog just issued by The McKay Company. Advice as to proper discrimination among different mild-steel electrodes, according to the nature and conditions of the work, is given in charts and comparisons that should be equally helpful to a user of either McKay Shielded-Arc Welding Electrodes or some other brand. The new catalog (E-16) may be had by writing the general sales offices of The McKay Company at York, Pa.

YOUR PRODUCT

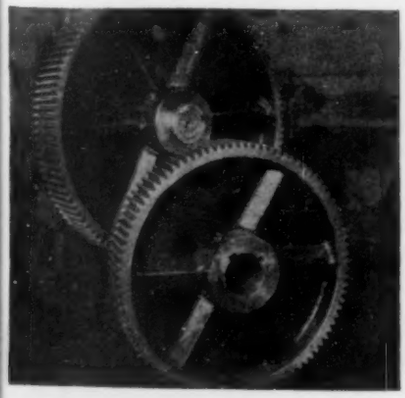
. . . *build it Faster, Lighter, Stronger, Cheaper, to Wear Longer and Look Better with*

U·S·S ROLLED STEELS

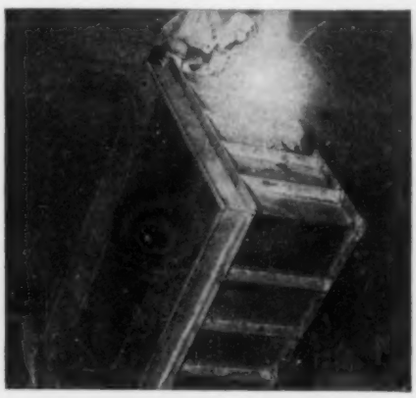
WELDED rolled steel construction is a 'natural.' That's why it has gained a wide acceptance in such a comparatively short time. Designers, fabricators and welders were quick to see that rolled steel construction placed at their disposal the entire range of metallurgy's special steels — permitted them to use these steels combined with one another, or with plain steels or castings, to improve their product and reduce its cost.

It will pay you to investigate the advantages that can be obtained with the special steels we offer for rolled steel construction: U·S·S COR-TEN to resist corrosion and COR-TEN and MAN-TEN to reduce weight or increase strength; U·S·S Abrasion Resisting Steel for use where abrasive conditions are exceptionally severe; U·S·S Heat Resisting Steels to combat high temperatures; U·S·S Stainless Steels to resist corrosion of all kinds; and U·S·S Carilloy Alloy Steels to carry tremendous bearing pressures.

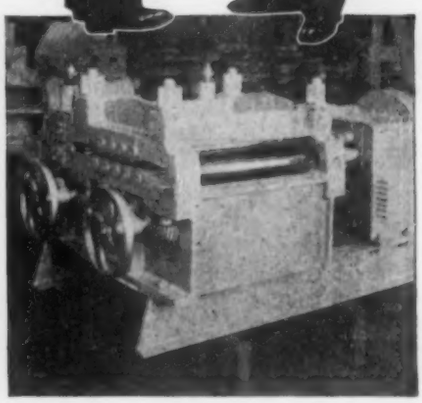
The photographs on this page illustrate the wide range of applications to which Rolled Steels are being put. We'll be glad to give you further information on these and many more jobs. Or, if you desire, a rolled steel specialist will talk with you personally about your own product—show you how, where and why construction with U·S·S Rolled Steel can improve it.



In large or small gear fabrication, rolled steel and welded construction can cut fabricating time and costs and give the gears longer life and greater strength. Records in our files show savings of 25% and more achieved with this type of construction.



Welding speeds construction of limestone cars . . . gives them longer life. The right steels, used in the right place, equip these cars for heavy duty service. Rolled steel construction lengthens their life, cuts weight and consequently reduces operating costs.



Rolled Steel and Castings effectively combined in this Roller Leveler. Savings in time resulting from this type of construction amounted to approximately 50% over the previous method used. Weight was cut 15%, cost reduced 5%.

This symbol represents the highest quality, the finest metallurgical service.

USS

CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
COLUMBIA STEEL COMPANY, *San Francisco*
TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*
United States Steel Export Company, New York

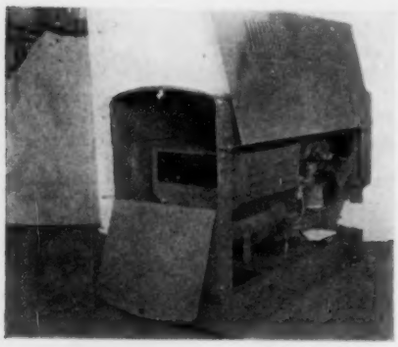
UNITED STATES STEEL

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

ENGINE-DRIVEN WELDER

A new 200-ampere engine-driven arc welder which is exceptional in light weight, small size and low cost for an engine-driven unit of its capacity, is anannounced by The Lincoln Electric Company, Cleveland.



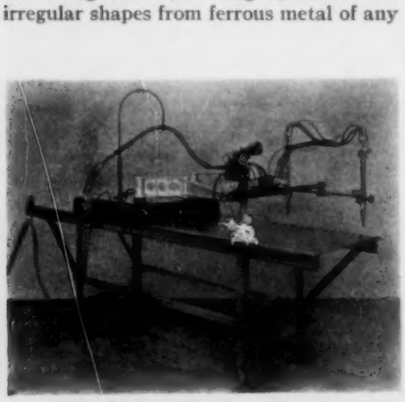
The new welder, designated the "SAE-200 J," is of the Junior type (see photo) and affords a new experience in moving and handling engine-driven welding equipment. It is light enough to be wheeled readily by one man, or lifted easily on its single balancing hook by average moderate-capacity chain or crane falls. The weight is under 900 pounds.

Ease of moving and handling the unit is further enhanced by its size which also shows to advantage in the matter of floor space.

Floor space required for the stationary model is only 8 square feet.

GAS CUTTER

The extreme flexibility of use of the new Airco No. 10 Planograph announced by Air Reduction Sales Company, New York, is demonstrated by its ability to gas cut straight lines, rectangles, circles and irregular shapes from ferrous metal of any thickness within the present practical limits of the cutting torch. Although a stationary-type machine, the new unit can readily be moved by crane to different localities in the shop.

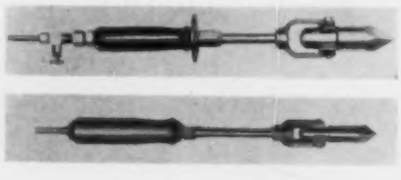


The No. 10 planograph consists of a tracing table upon which the carriage travels. The torches and tracing devices are supported on the carriage. Operating on either 110 or 220 volts a. c. or d. c., the unit requires a minimum of floor space. Even including the work table, the new planograph requires a working area of only $5^1/_2 \times 10^1/_2$ ft.

Cutting range in single torch operation is 24 in. wide by 72 in. long. This length can be increased indefinitely in multiples of 72 in. by utilizing additional tracing tables. Maximum diameter of circle cuts is 24 in. When two torches, mounted on the regular operating bar, are employed for simultaneous cutting, the cutting area for each torch is 12 in. wide by 72 in. long. Two circles each up to 12 in. diameter can also be cut with the torches mounted in this manner. By using an auxiliary bar, the cutting area of each is 24 x 24 in.

SOLDERING IRONS

Two new soldering irons of the open-flame type has been announced by The Linde Air Products Company, a Unit of Union Carbide and Carbon Corporation.



These soldering irons, available as part of the Prest-O-Lite line of air-acetylene equipment, offer distinct advantages to the user. A constant source of just the right amount of heat is provided by the air-acetylene flame. This heat is instantly available, and once the work is started there are no interruptions to reheat the copper, since the flame is an integral part of the soldering iron. In addition, the copper is kept at a constant temperature due to the stability of the flame. These factors mean increased operating speed with resultant economy, and unusually uniform results.

The small soldering iron is particularly well suited for automotive, electrical, telephone switchboard, and radio work, while the standard soldering irons are capable of handling all but the heaviest operations.

CHILL RING

Wedge Protectors, Inc., of 9544 Richmond Avenue, Cleveland, Ohio, announce the new WEDGE Backing or Chill Ring.

This new product has important features that make it valuable for use in industrial power plants and for any operation in the general industrial field involving the welding of pipe.

The spacing bead in the center of the WEDGE Chill Ring assures a joint of uniform width. This standardizes the amount of welding electrodes to be used on each joint, which controls the cost of this operation. A very important point is that with the WEDGE Chill Ring the welding operator can penetrate to the inside of the pipe with the first layer of weld metal. This eliminates the main cause of weld failure in pipe welding.

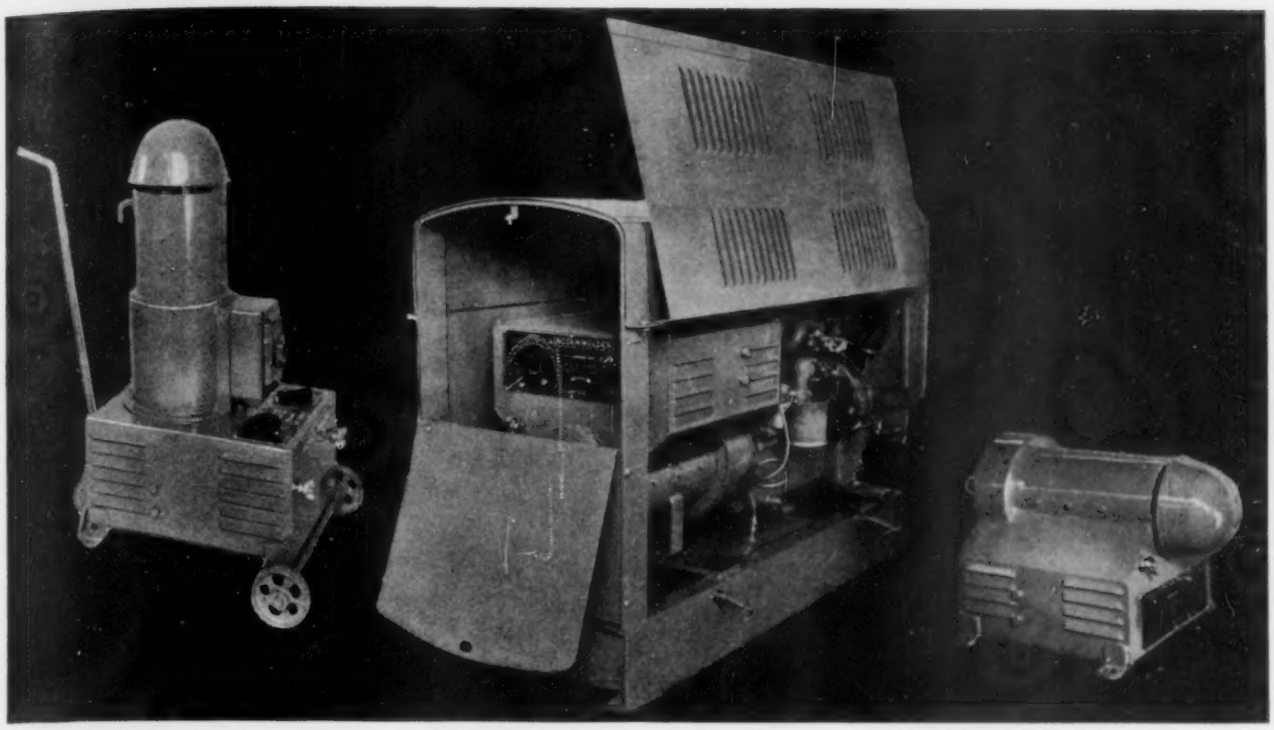
COMPOSITE METAL

Cleveland, Ohio, December 4, 1939.—A machine which produces a new composite metal of tremendous social and economic significance has been licensed for manufacture by the United Engineering and Foundry Company, Pittsburgh, Pa. The license has just been granted by R. E. Kinkead, widely known engineer and consultant in welding.

The new metal makes available—at cost savings of 15% to 20%—wearing qualities which are better and more lasting than those of competitive materials such as tin terne and galvanized steel. The new material is ordinary steel with the surface alloyed by addition of chromium and nickel.

Capable of being made in thicknesses comparable with paper—0.010 of an inch—the new metal can be produced within predetermined specifications. The process is also controllable for production of various alloys. Pickling, shot blasting, cold reduction, polishing or other operations may be carried out at costs which are customary with ordinary materials.

The new machine, which makes possible the production of this new composite metal, and which has just been licensed for manufacture, utilizes the Lincoln "Electronic Tornado" process of automatic carbon arc welding.



ELECTRIC DRIVE *"Shield-Arc Jr."*—world's most popular low-priced d.c. welder. For a wide range of welding and hard-facing applications. Uses as little as 5c worth of power per hour. In ratings of 75, 100, 150 and 200 amps. Price $158 to $243 F.O.B. Cleveland, freight prepaid.

ENGINE DRIVE—200-amp *"Shield-Arc Jr."* The new welder with a multitude of profitable uses in shop and field. Weighs less than 900 lbs., occupies floor space of less than 8 sq. ft., is little more than a yard high. Dependable industrial type engine. Price $450 F. O. B. Cleveland, freight prepaid.

COUPLED MODEL—New 200-amp. *"Shield-Arc Jr."*, operating at 1800 r.p.m., for "build-your-own" engine driven or motor-driven welders. Complete with Self-Indicating Dual Continuous Control. Lincoln's large-scale production makes this an unusually good buy. Price $235 F.O.B. Cleveland, freight prepaid.

NOW—A Complete Line of 200-AMP. "JUNIORS"

to give you D. C. WELDING *at lower cost*

PROFITABLE—Rated 40 to 250 amps. *direct current* gives you advantage of wide range of application including speedy welding of all common metals and alloys and hard-facing work of all types and sizes.

EXACT ARC CONTROL—"Job Selector" and current control—both continuous and self-indicating—give you the ideal TYPE of arc and arc INTENSITY for every job. No guessing. No compromise settings. You get the proper setting for highest weld quality and highest welding speed every time.

FOR SUSTAINED WELDING—Non-inflammable insulation at proper points permits sustained welding with relatively large size electrodes for faster work and lower cost.

Consult The Nearest Lincoln Office Or Mail The Coupon For Data On These New Profit-Making Welders

Largest Manufacturers of Arc Welding Equipment in the World

THE LINCOLN ELECTRIC CO.

CLEVELAND, OHIO

THE LINCOLN ELECTRIC CO., Dept. OD-658, Cleveland, Ohio

- ☐ 200-amp. Electric Driven "Junior."
- ☐ 200 amp. Engine Driven "Junior."
- ☐ 200 amp. Coupled Model "Junior."

Name _____ Position _____

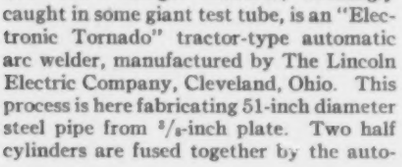
Company _____

Address _____

City _____ State _____

AUTOMATIC ARC WELDER

Symbolizing the flash and whirr of SPEED, sentinel of industrial production, this weird midget motorist, seemingly caught in some giant test tube, is an "Electronic Tornado" tractor-type automatic arc welder, manufactured by The Lincoln Electric Company, Cleveland, Ohio. This process is here fabricating 51-inch diameter steel pipe from $^3/_8$-inch plate. Two half cylinders are fused together by the automatic arc welder. The pipe, $13^1/_2$ miles of it, is for the Colorado River Aqueduct. It is being fabricated by Emsco Derrick and Equipment Company, Los Angeles, California.



Fabricated by automatic arc welding, the pipe is joined in the field by the manual shielded arc process.

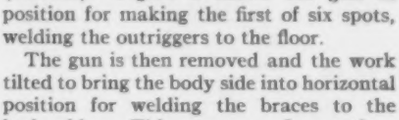
ASSEMBLING STANDARD DUMP BODIES

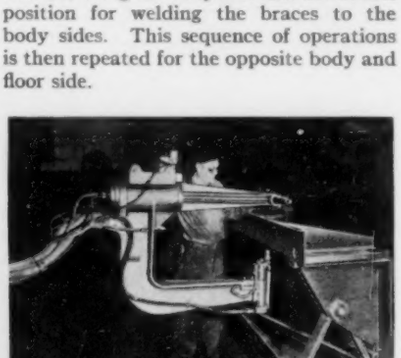
Standard dump bodies are now being assembled by spot welding at the truck plant of the Gar Wood Company in Detroit as the result of development of special deep-throated swivel-electrode guns of high capacity. The development has permitted the extensive use of formed steel gusset and reinforcing plates in standard bodies insuring high body strength without the use of heavy structural shapes requiring arc welding.

Employing a total of four heavy-duty spot-welding guns, designed and built by Progressive Welder Co., 737 Piquette Ave., Detroit, assembly is progressive in character. Steel is generally of 10 gage and comes to the welding department on a portable, tilting-top carrier which accommodates either a right- or left-hand floor section, one side of which forms one body side—the opposite side being formed into channel shape.

The first gun in the production line is used, first, to weld outriggers to right- and left-hand floor sections. In order to permit the welding electrodes to clear the channel (Fig. 1) the support bracket for the upper electrode is carried in the gun frame in such a manner that the electrode, by means of a self-locking lever manipulated by the operator, can be swiveled to a horizontal position. When the upper electrode has cleared the channel, the electrode is turned back to welding position (vertical). Figure 2 shows the gun in position for making the first of six spots, welding the outriggers to the floor.

The gun is then removed and the work tilted to bring the body side into horizontal position for welding the braces to the body sides. This sequence of operations is then repeated for the opposite body and floor side.





The same gun is now used for welding cross members to center floor section (longitudinals), the swivel feature of the gun again permitting the gun to clear the depth of both left- and right-hand channels which are formed out of the floor center.

The flexibility and clearance of this special gun are due largely to the use of sliding internal electrical contacts in the gun proper, greatly simplifying the design and permitting incorporation of rigidity in the gun frame.

MULTIPLE-OPERATOR WELDING SETS

Redesign of General Electric's 1500-ampere constant-potential arc-welding sets for multiple-operator and machine welding has resulted in more compact construction, lighter weight, improved appearance and greater ease of installation. In addition, the improved equipment has the control for the motor and generator mounted on the base, making for greater convenience for the operator.

Constant-potential motor-generator arc-welding sets are especially suited for supplying the heavy current demands of modern automatic welding and the exacting requirements of production hand-welding by a number of operators. Where a number of operators are to be supplied from one set, advantage can be taken of the fact that the average hand-welding operation is not continuous. This diversity factor of the welding load allows the use of a smaller-capacity set in supplying a given connected load than would be required if each operator were supplied by a separate set, and because one large machine supplying a number of welding stations can operate at all times near its most efficient load point.

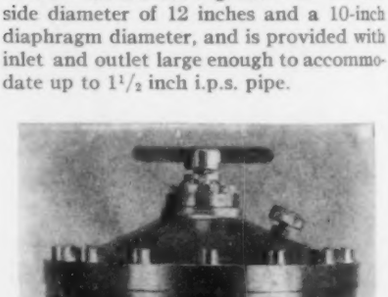
The sets are equipped with standard driving motors for operation on direct current, or on polyphase alternating current at any commercial voltage. Synchronous driving motors may be used to obtain plant power-factor improvement. This often results in materially reduced power bills.

REGULATOR FOR SCARFING OR DE-SEAMING

To supply the relatively large volumes of oxygen required for de-seaming and scarfing torches, Victor Equipment Company, 844 Folsom St., San Francisco, are now marketing a specially designed regulator Model No. L-150.

Owing to its large gas capacity, this regulator also serves adequately large compressed air installations where uniform pressure control is desired.

The Model L-150 regulator has an outside diameter of 12 inches and a 10-inch diaphragm diameter, and is provided with inlet and outlet large enough to accommodate up to $1^1/_2$ inch i.p.s. pipe.



The regulator is designed for inlet pressures up to 250 lb. and for delivery pressures up to approximately 225 lb. maximum.

OXYACETYLENE GOUGING

A series of new oxyacetylene gouging nozzles, for use with a standard hand-cutting blowpipe, such as the Oxweld C-32

Sections—CHAIRMEN, SECRETARIES AND REGULAR MEETING DATES

BIRMINGHAM — 3rd Fri.
CHAIRMAN—J. W. ADAMS, 209 No. 52nd St., Birmingham, Ala.
SECRETARY-TREAS.—W. L. POOLE, Air Reduction Sales Company, 2825 No. 29th Ave., Birmingham, Ala.

BOSTON — 3rd Mon.
CHAIRMAN—F. B. MEHAFFEY, Air Reduction Sales Co., 122 Mt. Vernon St., Upham Crs., Dorchester, Mass.
SECRETARY—P. N. RUGG, 8 Eastern Ave., Wakefield, Mass.

CANTON, OHIO (Akron, Alliance, etc.)
ROBERT M. WALLACE, The Griscom-Russell Company, Massillon, Ohio

CHATTANOOGA, TENN. — 1st Wed.
CHAIRMAN—A. R. MCLAIN, 622 Georgia Avenue, Apt. 110 Chattanooga, Tenn.
SECRETARY—J. H. WEIGEL, 117 Ochs Highway, Chattanooga, Tenn.

CHICAGO — 3rd Fri.
CHAIRMAN—E. A. BALSLEY, Link-Belt Co., 300 W. Pershing Rd, Chicago Ill.
SECRETARY—M. S. HENDRICKS, Welding Engineer, Room 731, 506 South Wabash Avenue

CINCINNATI, OHIO
CHAIRMAN—JAMES K. ROSS, United Welding Co., Box 247, Middletown, Ohio
SECRETARY—LEWIS B. BLAKENEY, Westinghouse E. & M. Co., 207 N. 3rd St., Cincinnati, Ohio

CLEVELAND — 2nd Wed.
CHAIRMAN—F. L. PLUMMER, 2591 Charney Rd.
SECRETARY-TREAS.—A. LESLIE PFEIL, Universal Power Corporation, Cleveland, Ohio

COLORADO — 3rd Wed.
CHAIRMAN—J. H. JOHNSON, Johnson Supply Co., Denver, Colo.
SECRETARY-TREAS.—H. W. CREAGER, Hendrie & Bolthoff Mfg. & Supply Co., Denver, Colo.

COLUMBUS, OHIO — 2nd Fri.
CHAIRMAN—F. S. CALDWELL, Jeffrey Mfg. Co., Columbus, Ohio
SECRETARY—G. S. HERREN, The Seagrave Corp., Columbus, Ohio

CONNECTICUT — 1st Tues.
CHAIRMAN—JOHN J. VREELAND, Chase Brass & Copper Co., Waterbury, Conn.
SECRETARY—H. A. PENNINGTON, A. B. King & Co., 196 Chapel Street, New Haven, Conn.

DETROIT — 1st or 2nd Fri.
CHAIRMAN—H. P. DOUD, General Electric Co., 700 Antoinette, Detroit
SECRETARY—O. L. SMITH, Weldit Acetylene Co., 638 Bagley, Detroit, Mich.

GEORGIA — 1st Mon.
CHAIRMAN—D. B. HUNT, 484 Brentwood Dr. N. E., Atlanta, Ga.
SECRETARY—H. J. LEE, P. O. Box 4564, Atlanta, Ga.

HAWAII — 4th Tues.
CHAIRMAN—ROBERT A. PLAUS, W. A. Ramsay, Ltd., Honolulu, T. H.
SECRETARY—ALAN G. SLIPPER, Hawaiian Gas Products Co., P. O. Box 2454, Honolulu, T. H

INDIANA
CHAIRMAN—A. C. RASMUSSEN, Insley Mfg. Corp., Indianapolis, Ind.
SECRETARY—G. HAISLUP, Electric Steel Castings Co., Speedway City, Indianapolis, Ind.

KANSAS CITY, MO. — 3rd Mon.
CHAIRMAN—J. L. FIZZELL, National Steel Prods. Co., Kansas City, Mo.
SECRETARY—JAMES P. KIRK, Air Reduction Sales Co., Kansas City, Mo.

LOS ANGELES — 3rd Thurs.
CHAIRMAN—C. P. SANDER, Western Pipe & Steel Co., Los Angeles. Calif.
SECRETARY,—J. C. GOWING, 644 E. Florence Ave., Los Angeles, Calif.

LOUISIANA — 1st Fri.
CHAIRMAN—O. B. MCLAUGHLAN, Freeport Sulphur Co., Port Sulphur La.
SECRETARY—CLYDE PINE, The Isaac Delgado Trade School, New Orleans, La.

MARYLAND — 3rd Fri. except April
CHAIRMAN—C. N. HILBINGER, T. A. Canty, Inc., Baltimore, Md.
SECRETARY-TREAS.—R. A. MANSFIELD, Southern Oxygen Co., Baltimore, Md.

MEMPHIS
CHAIRMAN—E. H. GILL, National Butane Gas Co., Memphis, Tenn.

MILWAUKEE — 2nd Wed.
CHAIRMAN—R. W. STERNKE, Lakeside Bridge & Steel Co., Milwaukee, Wis.
SECRETARY—GILBERT F. MEYER, Machinery & Welder Corp., Milwaukee, Wis.

NEW YORK — 2nd Tues. except when Joint Meeting is held
CHAIRMAN—CHARLES KANDEL, Craftsweld Equipment Co., Long Island City, N. Y.
SECRETARY—G. V. SLOTTMAN, Air Reduction Sales Co., 60 East 42nd Street, New York, N. Y.

NORTHWEST — 3rd Wed.
CHAIRMAN—T. J. WARMINGTON, Wm. Bros. Boiler & Mfg. Co., Minneapolis, Minn.
SECRETARY—ALEXIS CASWELL, Manufacturers Assoc. of Minn., 200 Builders Exchange Bldg., Minneapolis, Minn.

NORTHERN N. Y. — Last Thurs.
CHAIRMAN—R. W. CLARK, General Electric Company, Schenectady, N. Y.
SECRETARY—G. A. ROSS, General Electric Co., Schenectady, N. Y.

OKLAHOMA CITY — 1st Fri.
CHAIRMAN—K. B. BANKS, P. O. Box 1377, Oklahoma City, Okla.
SECRETARY—C. C. WILLIS, P. O. Box 1498, Oklahoma City, Okla.

OMAHA, NEBRASKA — 2nd Thurs.
CHAIRMAN—L. B. THOMAS, Economy Welding Service, 18th & Cuning Sts., Omaha, Nebr.
SECRETARY—G. E. MCGRATH, McGrath Welding Co., 4026 Nicholas, Omaha, Nebr.

PEORIA—CENTRAL ILLINOIS
CHAIRMAN—E. E. ISGREN, R. G. Le Tourneau, Inc., Peoria, Ill.
SECRETARY—W. J. BROOKING, 855 Virginia Ave., Peoria, Ill.

PHILADELPHIA — 3rd Mon.
CHAIRMAN—H. R. SALISBURY, Air Reduction Sales Co., Allegheny & 17th Sts., Phila., Pa.
SECRETARY—H. E. HOPKINS, Arcos Corp., 401 N. Broad St., Phila., Pa.

PITTSBURGH — Middle Wed.
CHAIRMAN—G. F. WOLFE, Dravo Corp., Engineering Wks. Div., Pittsburgh, Pa.
SECRETARY—J. F. MINNOTTE, Minnotte Bros., 1201 House Bldg., Pittsburgh

PUGET SOUND
CHAIRMAN—H. HAYNES, Commercial Boiler Wks., 53 W. Lander St., Seattle, Washington
SECRETARY—L. A. BURQUE, Westinghouse Elec. & Mfg. Co., Seattle, Washington

QUAD CITIES
CHAIRMAN—A. R. GUSTAFSON, 840 Third Ave., Moline, Illinois
SECRETARY—J. W. SHUGARS, Lincoln Elec. Co., Moline, Illinois

ROCHESTER, N. Y. — 1st Thurs.
CHAIRMAN—EDWIN ALLAN, Allan Iron & Welding Wks., Inc., 133 Murray St.
SECRETARY—PAUL W. JAMES, Lincoln Electric Co., 17 Lake View Park, Rochester, N. Y.

SAN FRANCISCO — Last Fri.
CHAIRMAN—T. R. ROONEY, Western Pipe & Steel Co., San Francisco,, Calif.
SECRETARY—J. G. BOLLINGER, Air Reduction Sales, Park & Halleck Sts., Emeryville, Calif.

SAN JOAQUIN VALLEY
CHAIRMAN—G. D. ATMORE, 401 Santa Barbara St., Santa Paula, Calif.
SECRETARY—A. W. SCHERER, 918 Quincey St., Bakerfield, Calif.

ST. LOUIS — 2nd Fri.
CHAIRMAN—N. F. MOSS, 7508 Wayne, St. Louis, Mo.
SECRETARY—M. E. MEYERSON, 2317 Chouteau Ave., St. Louis, Mo.

SOUTH TEXAS
CHAIRMAN—B. W. FARQUHAR, Gulf Oil Corp., Port Arthur, Texas
SECRETARY—T. D. KETCHBAW, Industrial Welding & Testing Lab., Houston, Texas

TULSA, OKLAHOMA
CHAIRMAN—G. L. WILEY, Box 226, W. Tulsa, Okla.
SECRETARY—O. L. ROGERS, Big Three Welding & Equipment Company, Tulsa, Okla.

WASHINGTON, D. C. — 2nd Tues.
CHAIRMAN—C. A. LOOMIS, Bureau of C. & R. Navy Dept., Washington, D. C.
SECRETARY—G. E. KNOX, Bureau of Yards & Docks, Navy Dept., Washington, D. C.

WESTERN NEW YORK — Last Mon.
CHAIRMAN—J. R. DAWSON, Union Carbide and Carbon Res. Labs., Niagara Falls, N. Y.
SECRETARY—C. S. FREEMAN, The Lincoln Electric Company, Buffalo, N. Y.

WICHITA, KANSAS
CHAIRMAN—L. E. KIRK, Vickers Petroleum Co., Wichita, Kansas
SECRETARY-TREAS.—K. O. HOUSER, Kansas Gas & Electric Co., Wichita, Kansas

YORK—CENTRAL PENNA.
CHAIRMAN—J. W. HENNESSEY, York Safe & Lock Co., York, Pa.
SECRETARY—C. B. HERRICK, 628 S. Pershing Ave., York, Pa.

YOUNGSTOWN (OHIO) — 2nd Mon.
CHAIRMAN—E. W. TROSS, United Eng. & Fdy. Co., Youngstown, Ohio
SECRETARY-TREAS.—C. R. RIGGLE, Ohio Edison Co., Youngstown, Ohio

cutting blowpipe, has been announced by The Linde Air Products Company. These new Oxweld nozzles, which are available in three sizes, provide a means for quickly and accurately removing a narrow strip of surface metal from steel plate, forgings and castings.

The nozzles are so designed as to deliver a relatively large jet of oxygen at low velocity. By proper manipulation of the blowpipe in which the nozzle has been inserted, a smooth, accurately defined groove can be cut or gouged out of the surface of the metal. By using various standard size nozzles and manipulations, the groove can be varied in width and depth at the will of the operator.

Important uses for these new nozzles are: gouging the underside of electric welds; removal of weld metal, such as temporary tack-welds and defective welds; preparation of plate edges for welding; and maintenance and scrapping operations. A wide field of miscellaneous uses includes gouging in metal-shaping and trimming processes.

ARC TORCH

One of the important achievements recently contributed to the welding industry is the new Marquette Arc Torch announced by the Marquette Manufacturing Co. of Minneapolis, Minn.

A.C. and D.C. arc-welding users have long been handicapped by lack of a suitable attachment for doing the many heating and welding jobs that demand an independent source of heat such as supplied by the gas torch.

With the Marquette Arc Torch and A.C. welding current that difficulty has been largely overcome. With the new equipment it is now possible to do general heating jobs; preheating; welding of aluminum, bronze, copper, pot metal, German Silver and other non-ferrous metals; braze; solder; and apply hard surfacing paste.

WELDING POSITIONER

Capacity is based on center of gravity of load 12 inches from face of table and also with center of gravity of load 6 inches to the side of the axis of rotation. Capacity 6000 lb.

Table can be rotated through a full circle regardless of angle at which it is tilted.

Table can be tilted through an arc of 135° from horizontal position.

Gears for rotating the table and tilting the table are self-locking in all positions. Rotating and tilting movements are each controlled by independent motors and controls.

Height of table is adjustable from 42 inches to 54 inches on machines with standard bases. Positioner can be furnished with a special mounting for handling extremely large work.

Table can be removed so special fixtures or jigs can be mounted directly on Positioner. Cullen-Friestedt Company, 1300 South Kilbourn Avenue, Chicago. Ill.

IRON FIREMAN

Arc welding enables the Iron Fireman Manufacturing Company to produce a more efficient and longer-lived coal conveyor worm for use in its domestic, commercial and industrial stokers. Here an operator is welding cold-rolled and twisted conveyor worm flights to solid steel cores. The process is more flexible than the steel casting operation previously used. It

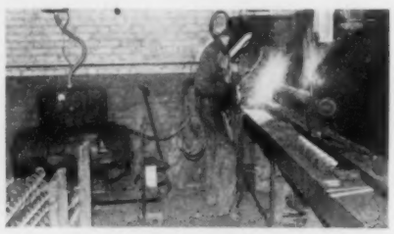


Photo courtesy General Electric Co.

produces a uniformly true worm, and permits the use of flights of two thicknesses on the same worm, for greater stoker efficiency. This feature cuts down wear and adds materially to the life of the worm.

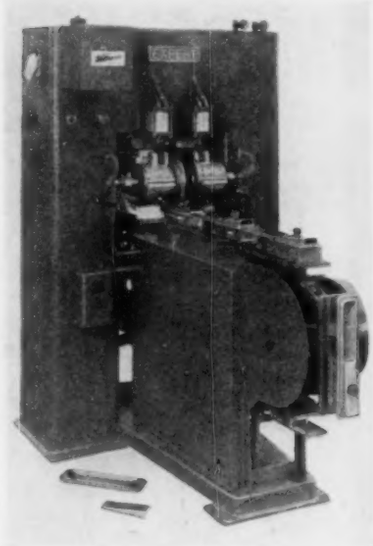
It also makes possible the use of special alloy steel flights on the tip end of the conveyor worm. These flights resist wear and corrosion, resulting in longer life.

SPOT WELDS WITH SEAMWELDER

Continuous automatic spot welding—using a seamwelder—is a striking innovation recently placed in operation in a prominent motor plant. The operation is made possible largely by the adaptation to a seamwelder of a standard Weltronic weld-timer which accurately controls length of time current is on and current is off, and provides an automatic repeating cycle.

Designed and built by Expert Welding Machine Company, Detroit, the machine is not only able to make accurately spaced spots, but also by means of an adjustable timer control is enabled to adjust the size (length) of spots to the exact amount desired, irrespective of production rate.

Designed for the purpose of series spot welding 19 gage oil baffle plates to 18 gage valve cover plates for both six and eight cylinder cars, the new welder includes a conveyor for carrying the work under the "seam" rolls, a 50 kva. transformer, timer, contactor, etc., and is thus completely self-contained.



Weltronic Interrupting Weld-Timer Enables Continuous Operating Seamwelder to Spot Weld Oil Baffle Plate to Valve Cover Plate

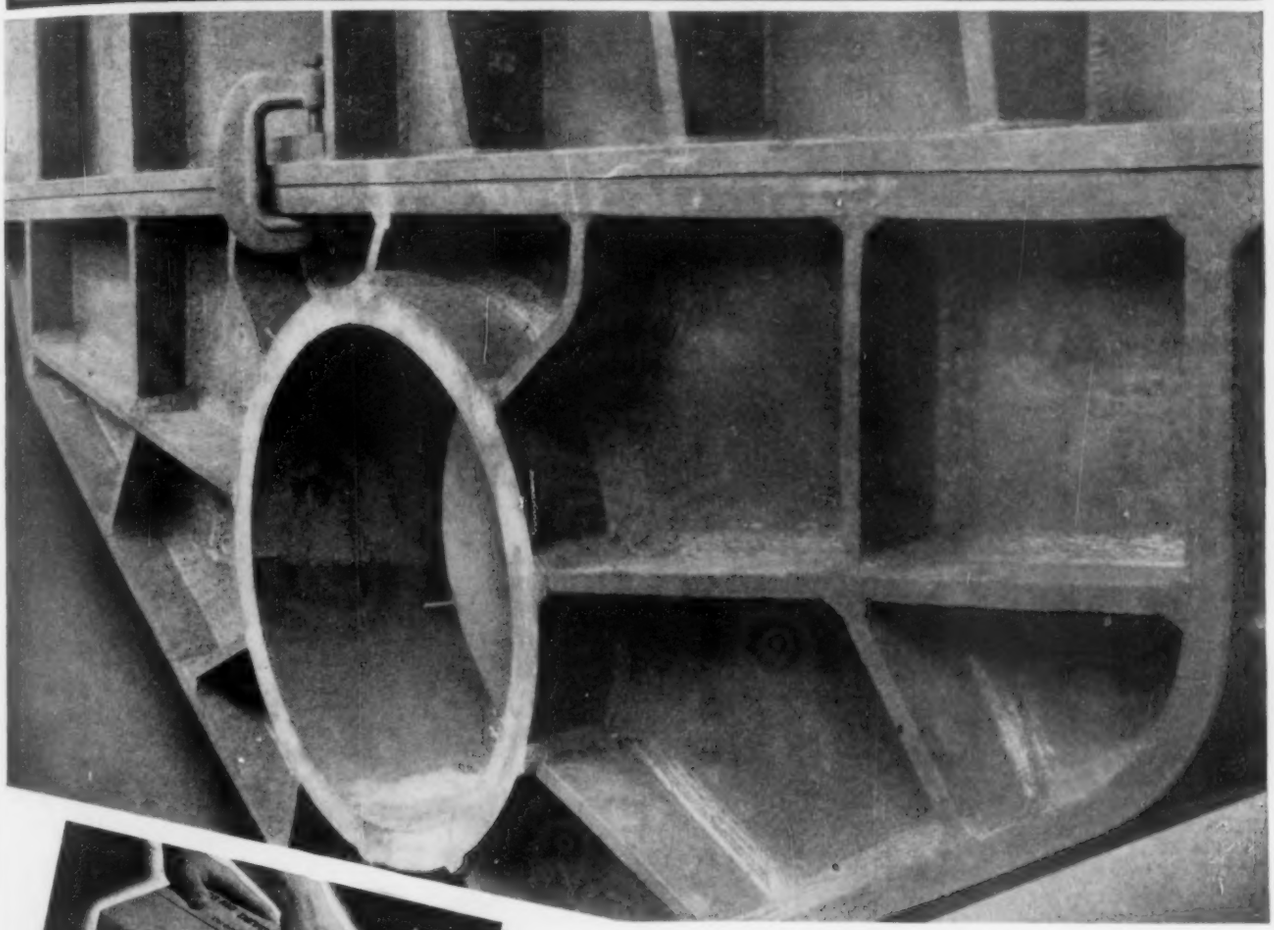
Although designed for a production speed of 450 pieces per hour, the machine is readily adjustable to suit any speed needed in relation to flow of parts in production. It thus eliminates the necessity for storage of either finished or unfinished work at the machine—parts being welded at the same rate as supplied. Change in conveyor speed is quickly compensated for by changing the dial setting on the timer, thus retaining the same length and spacing of spots irrespective of production rate.

SOCIETY EMBLEMS

These emblems are available in 2 sizes—½ inch square and ¼ inch square. The prices in both cases are as follows:

	Price
Gold-Plated emblem with screw back attachment	$ .40
Gold-Plated emblem with safety lock catch	.50
8 K. Gold—with screw back attachment	$2.50
8 K. Gold—with safety lock catch	$2.55

No Kicks Thanks to Champion Electrodes



CHAMPION Welding Electrodes are packed in a heavy corrugated cardboard shipping container which is sealed on all sides, and there is imbedded in the cover a wire with a loop to facilitate easy opening. Try CHAMPION Red Devil, Blue Devil, Gray Devil or Black Devil Electrodes—there is a type to meet your exacting requirements. . . . *Send for descriptive folder.*

THIS illustration shows the rear view of what is believed to be the heaviest piece of built up structural steel ever fabricated by electric welding . . . . The design of this structure called for very substantial fillet welds with exceptional physical properties. CHAMPION Electrodes were used throughout with ***complete satisfaction.***

THE CHAMPION RIVET COMPANY

CLEVELAND, OHIO **EAST CHICAGO, INDIANA**

» » » SECTION ACTIVITIES « « «

BOSTON

The following are the programs of coming meetings of the Boston Section.

January 8, 1940. Meeting place: Massachusetts Institute of Technology, Room 4-270. Speaker: Mr. J. I. Wilson, Asst. Chief Surveyor, American Bureau of Shipping. Subject: "The Relationship Between Welding and Shipping."

January 16, 1940. Meeting place: Providence Engineering Society Building, 195 Angell Street, Providence, R. I. Speaker: Mr. Charles H. Jennings, Westinghouse Elec. & Mfg. Co. Subject: "Welded Design."

January 17, 1940 (Joint meeting with American Society for Metals). Meeting place: Worcester Polytechnic Institute, Sanford Riley Hall, Worcester, Mass. Speaker: Mr. Charles H. Jennings. Subject: "Welded Design."

February 12, 1940. Meeting place: Massachusetts Institute of Technology, Room 4-270. Speaker: Mr. L. T. Benoit, District Service Engineer, The Linde Air Products Co. of Boston. Subject: "Hard Facing of Metals by Welding." Speaker: Mr. C. M. Manzer, Manufacturing Methods Dept., General Electric Co. Subject: "Controlled Brazing."

March 11, 1940. Meeting place: Massachusetts Institute of Technology, Room 4-270. Speaker: Dr. V. N. Krivobok, Asst. Director of Research, Allegheny Ludlum Steel Corp. Subject: "The Welding of Stainless Steels."

April 8, 1940. Meeting place: Massachusetts Institute of Technology, Room 4-270. Speaker: Dr. Charles W. Briggs, Technical Adviser, Steel Founders' Society of America. Subject: "Steel Castings and Welded Structures." Speaker: Mr. Vincent T. Malcolm, Metallurgical Engineer, Chapman Valve Manufacturing Co. Subject: "The Common Problems of the Foundryman, Engineer and Welder."

CHATTANOOGA

The Chattanooga Section of the AMERICAN WELDING SOCIETY held their first meeting of the season Thursday evening October 9th, at the Hotel Patten. The meeting opened by installing new officers for the coming year, which are as follows: Mr. A. R. McLain, Chairman; Mr. Bert L. Syler, Vice-Chairman; Mr. John Henry Weigel, Secretary-Treasurer.

The meeting was in the form of a round table discussion led as follows: Mr. Mark Holt, of the Chattanooga Welding & Machine Company, led the discussion on "Job Welding." Mr. E. T. Welch, of the Chattanooga Vocational School, led the discussion on the "Educational Program." Mr. Robert Daniels, of Lincoln Electric Company, led the discussion on the "General Application of Welding from a Sales Standpoint." Mr. A. C. Richardson, of Combustion Engineering Company, led the discussion on "Light Plate and Structural Welding." Mr. Robert Christie, of Wheland Company, led the discussion on "Welding of Castings." Mr. Freeman and Mr. Lane, of Lucey Boiler & Mfg. Corp. led the discussion on "Oil Field Boilers." Mr. C. T. Raymo, of Chattanooga Boiler & Tank Company, led the discussion on "Structural and Light Tank Welding." Mr. E. C. Chapman, of Combustion Engineering Company, led the discussion on "Welding of Stainless Steels." Mr. A. R. McLain, of Combustion Engineering Company, led the discussion on "Unionmelt Welding."

The November meeting was held on the 16th. In opening the meeting, a brief discussion was called for anyone to present his problems in welding to the other members of the SOCIETY.

The main feature of the meeting was a technicolor sound picture, "Steel—Man's Servant," furnished by the U. S. Steel Corporation. Mr. Taylor Moore, of Tennessee Coal, Iron & Railroad Company discussed the picture with the members and answered all questions pertaining to the film and the steel industry.

The regular monthly meeting was held on December 5th at the Hotel Patten. Approximately sixty members and guests were present.

The principal speaker of the evening was Mr. R. F. Wyer, Welding Engineer, General Electric Company, Schenectady, N. Y. His subject was "Alternating Current Arc Welding." His discussion included growth of A.C. arc welding, fundamental difference between A.C. and D.C., time constant of the arc and arc stability. He also discussed the equipment necessary for A.C. welding, bringing out the advantages and disadvantages of both A.C. and D.C. welding.

CHICAGO

A Get-Together Dinner in The Electric Club preceded the regular monthly meeting of the Chicago Section held on Friday, November 17th, at the Chicago Lighting Institute. Dr. W. A. Pearl of the Armour Institute of Technology, presented an extremely interesting address on "Weld Zone and Pre- and Post-Welding Stresses."

CLEVELAND

The regular monthly meeting of the Cleveland Section was held on December 13th at the Cleveland Club, preceded by a dinner. Mr. J. M. Unger, Development Engineer, Pullman-Standard Car Manufacturing Company, presented an illustrated talk on "Welding in the Manufacture of Railroad Cars." Slides and motion pictures were shown.

Mr. E. W. Forker, addressed the January 10th meeting on the subject, "Manufacture of Process Machinery by Arc and Hammer Welding and Gas Cutting."

COLORADO

The November meeting of this Section was held on the 8th in the Public Service Auditorium. Mr. Lowry and Mr. Gallogly gave a discussion on Field Welded Storage Tanks. Mr. Creager gave a résumé of the Annual Meeting and Metal Show which he attended in Chicago.

COLUMBUS

Subjects and speakers and regular meeting dates of coming meetings of the Columbus Section are as follows.

January 12, 1940—Dinner Meeting, Hotel Fort Hayes. Speaker: Col. N. F. Ramsey, Rock Island Arsenal. Subject: "Development of Field Artillery."

February 9, 1940—Batelle Memorial Institute. Speaker: T. M. Jasper, A. O. Smith Corp. Subject: "Boiler and Insurance Underwriter Standards."

March 8, 1940—Dinner Meeting, Hotel Fort Hayes. Speaker: E. A. Mallett, V.-P. in charge of Engr., Taylor Winfield Corp. Subject: "Latest Developments in Resistance Welding."

April 12, 1940—Dinner Meeting, Hotel Fort Hayes. Speaker: R. G. Briggs, The American Brass Co. Subject: "Welding of Everdur and its Applications." Also film, "From Mine to Consumer—the Story of Anaconda."

May 10, 1940—Batelle Memorial Institute. Outline of Activities and a Conducted Tour of Batelle Memorial Institute.

DETROIT

The November meeting of the Detroit Section was held on the 3rd in the Detroit-Leland Hotel. Mr. H. C. Hettelsater, Engineer, Harnischfeger Corporation, spoke on the subject, "Designing Construction Machinery for Production by Welding." Through the courtesy of the A. O. Smith Corporation, a unique motion picture of flash-welding operations was presented, showing, in slow motion, arcing and the expulsion of metal during approach and completion of the weld.

SEAM WELDING

Roller Seam Welding can be applied to many existing jobs which require a gas or liquid tight joining of component parts. This type of welding procedure is especially adapted to Gasoline tanks, floats, cylindrical shapes, etc. It is sometimes used in roller spot operations to stitch weld; the spots being spaced at regular intervals. Speed of weld varies with thickness and properties of stock to be welded. It is also controlled by the requirements of the particular application. If your savings are affected due to this method of welding not receiving proper consideration in your plant, feel free to consult any of the companies listed below.

Resistance Welder Manufacturers' Association

505 Arch Street — Philadelphia, Pa.

MEMBER COMPANIES

Acme Electric Welder Company, Los Angeles
American Electric Fusion Corporation, Chicago
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Company, Detroit
Federal Machine and Welder Company, Warren
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City
Progressive Welder Company, Detroit
Swift Electric Welder Company, Detroit
Taylor-Hall Welding Corporation, Worcester
Taylor-Winfield Corporation, Warren
Thomson-Gibb Electric Welding Co., Lynn
Welding Machines Mfg. Company, Detroit

ASSOCIATE MEMBER COMPANIES

P. R. Mallory and Co., Indianapolis
S-M-S Corporation, Detroit
Electroloy, Inc., New York
Welding Sales and Engineering Co., Detroit

At the December 1st meeting Mr. George F. Emery and Mr. Harry Broad, Department of Buildings and Safety Engineering, Bureau of Buildings, City of Detroit, discussed the subject, "Licensing of Structural Welders."

GEORGIA

The Georgia Section held its regular monthly meeting on November 3rd at the Piedmont Hotel, Atlanta. Dinner was served preceding the meeting. A general discussion on a code for welding in the City of Atlanta, was held. An amendment was submitted and discussed. A vote was taken to adopt the A. W. S. Code.

MARYLAND

Mr. R. C. Fitzgerald of Consolidated Gas and Electric Co., Baltimore, Md., will lecture on the practical application of welding, at the January 19, 1940, meeting of the Maryland Section, to be held at the Engineers' Club, 6 W. Fayette Street, Baltimore, Md.

MILWAUKEE

Dinner and an After-Dinner Talk preceded the November 24th meeting of this Section which took place at the City Club of Milwaukee. The Welding Address was presented by Mr. James Thomson, Chief Plant Engineer of Continental Roll and Steel Foundry Co., E. Chicago, Indiana, who spoke on "Engineering Uses of Steel Castings in Welded Structures." Mr. Thomson's talk was illustrated by slides showing an actual production job and the combination of castings, steel plate and welding.

The December meeting was held on the 15th. The After-Dinner Talk was given by Dr. F. Massopust, who spoke on "Color Pictures of the Human Body with Infra-Red Ray Light." The Welding Address was given by A. E. Gibson, President, The Wellman Engineering Co., Cleveland, Ohio, who spoke on "Design Effecting Welding Cost."

NEW YORK

A Joint Technical Meeting of the New York Section, AMERICAN WELDING SOCIETY and the Metropolitan Section, the American Society of Mechanical Engineers was held on Wednesday, November 15, 1939, at 7:30 P.M. in the auditorium of the Engineering Societies Building, 33 W. 39th St., New York, N. Y. The chairman was Dr. D. S. Jacobus, Advisory Engineer, the Babcock & Wilcox Company. The first speaker was Mr. J. T. Phillips, Superintendent of Boiler Shop, Foster Wheeler Corporation, Carteret, New Jersey Works. His subject was "Welding of Pressure Vessels." Mr. Phillips discussed the effect of design on welding and showed shop views of work in progress. He also took up the subject of distortion due to welding and the effect on physical properties of weld metal deposited by different procedures. The second speaker was Mr. J. F. Bechtle, Welding Engineer, the M. W. Kellogg Company. Mr. Bechtle's subject was "The Fabrication of Large Diameter Pressure Vessels." Mr. Bechtle described some of the vital points to be considered in the fabrication of large diameter pressure vessels, over those normally encountered with smaller diameter pressure vessels.

Both papers were accompanied by interesting lantern slides. The subjects were very timely and were received with a great deal of interest by the audience. Over 600 persons attended the meeting, which was a very successful one from every point of view.

Advance program of meetings, 1940: Tues., Jan. 9—Gas Machine Cutting; Tues., Feb. 13—Flame Treatment of Steels; Tues., Mar. 12—Ship Welding; Tues., Apr. 9—Weldability of Steels; Tues., May 14—Aircraft Welding. Unless otherwise specified on program, all Regular Technical Meetings will be held in Engineering Societies Building, 33 West 39th Street, New York, N. Y., starting promptly at 7:30 P.M.

NORTHERN NEW YORK

The following are the officers and committees of the Northern New York Section for 1939–1940.

Chairman, R. W. Clark; First Vice-Chairman, W. C. Hutchins; Second Vice-Chairman, E. F. Potter; Secretary-Treasurer, G. A. Ross.

Executive Committee: (term expires May 1940) E. J. Myers and A. F. Stiglmeier; (term expires May 1941) E. R. Spittler and E. J. Ramer; (term expires May 1942) F. H. Miller and G. G. Somerville.

Meetings and Papers: A. C. Stevens, Chairman, W. F. Hess, H. O. Westendarp, E. J. Edwards, J. J. Weldon.

Membership: E. R. Spittler, Chairman, R. F. Wyer, A. F. Steiglmeier, J. R. Lipsky, C. F. Kuhlberg, E. J. Ramer, E. F. Potter.

Public Relations: W. F. Hess, Chairman, W. C. Hutchins, J. E. Waugh.

Education: F. H. Miller, Chairman, W. C. Hutchins, G. A. Ross, W. F. Hess, E. F. Potter.

Nominating: J. E. Waugh, Chairman, R. T. Gillette, E. J. Edwards, W. F. Hess, J. J. Weldon.

Coordinating: G. A. Ross, A. C. Stevens.

WESTERN NEW YORK

The Western New York Section had a very successful meeting on November 30th. Mr. J. H. Zimmerman of The Linde Air Products Company, New York City, spoke on "Flame Treating." The turnout was so large there was difficulty in finding seats for everyone. The lecture was illustrated with slides and movies and was well received.

The next meeting of the Section will be on January 18, 1940. Mr. Charles H. Jennings, Westinghouse Electric & Mfg. Company, will speak on "Distortion Problems in Welding." The meeting will be held in the Electric Building, 535 Washington St., Buffalo, N. Y., at 8 P.M. Visiting members and others interested will be welcome.

NORTHWEST

Mr. L. F. Nenninger, Chief Engineer, Cincinnati Milling Machine Company, Cincinnati, Ohio, addressed the members of the Northwest Section at its regular meeting on November 14th at the Minnesota Union, University of Minnesota, on the subject of "Welding Machine Tool Structures." Over one hundred members and guests were present and were very much impressed with Mr. Nenninger's presentation of his subject, which was most interesting. Chairman T. J. Warmington presided at the meeting and introduced the speaker.

Before the technical session two films were shown, one being by the Hennepin County Tuberculosis Association depicting the results of the efforts of that association to reduce tuberculosis infection, and the other film, "Packaging—A Public Service."

Mimeographed references on "Welding of Corrosion Resistant and Stainless Steel," compiled by T. P. Hughes, Vice-Chairman of the Section and Assistant Professor of Mechanical Engineering, University of Minnesota, were distributed.

OKLAHOMA CITY

The Oklahoma City Section held its regular monthly meeting at the Biltmore Hotel at 8:00 P.M., November 3rd. Mr. Jack Singleton, District Engineer, American Institute of Steel Construction, Topeka, Kansas, gave a very interesting talk on "Welded Steel Buildings," pointing out the saving in this class of construction over the regular riveted joint construction. He showed slides of typical welded joints in building structures, and others showing an initial draft of a code for welding of structural steel by the American Institute of Steel Construction.

After the address by Mr. Singleton, two films on "Manufactured Abrasives" were shown. There were 46 present at the meeting.

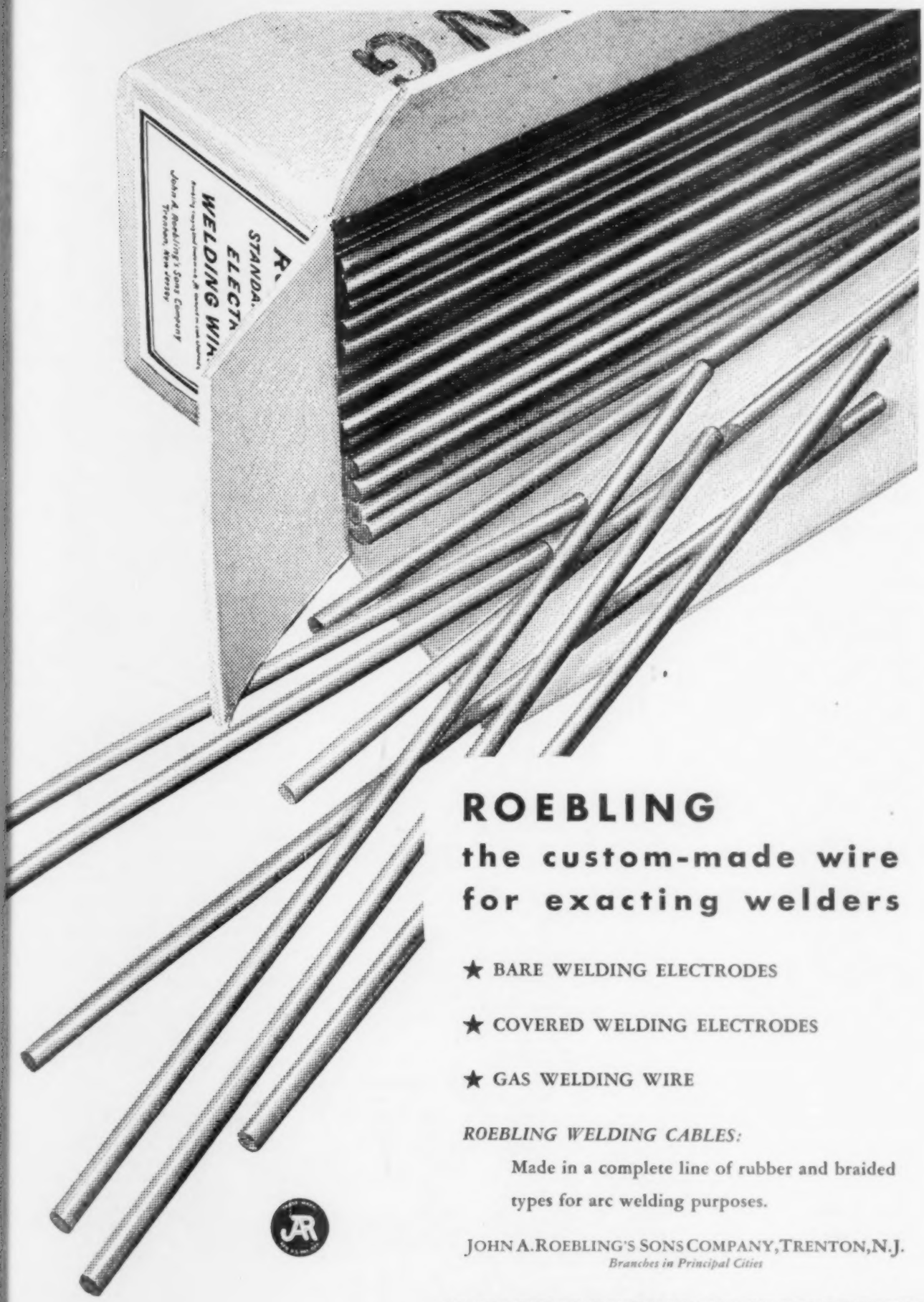
On Friday evening, December 1st, the Oklahoma City Section of the AMERICAN WELDING SOCIETY held its regular December meeting in Parlor "A" of the Biltmore Hotel. This was a dinner meeting. During the dinner entertainment was furnished by Mr. Bill Morris, pianist.

Immediately following the dinner a two-reel motion picture on "The Story of Lead Smelting" by the St. Joseph Lead Company, was shown. The main address on "Welded Joints—Which Ones to Use and Why" was given by Mr. Leon C. Bibber, Welding Engineer, Carnegie Steel Company, Pittsburgh, Pa. A number of questions were asked on the subject of joints and considerable discussion followed Mr. Bibber's description of the welding symbols.

There were 23 present for dinner, which number was increased to 47 for the address and discussions following the dinner.

PEORIA

On November 1st, Mr. F. C. Fantz, Vice-President of the Midwest Piping and Supply Company, St. Louis, Mo., presented a lecture on the design and welding



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★ GAS WELDING WIRE

ROEBLING WELDING CABLES:

Made in a complete line of rubber and braided types for arc welding purposes.

JOHN A. ROEBLING'S SONS COMPANY, TRENTON, N.J.
Branches in Principal Cities

ONLY A FINE PRODUCT MAY BEAR THE NAME ROEBLING

of high-pressure and high-temperature piping. About 65 members and guests attended the lecture. The lecture graphically explained the importance of design and its effect upon arc welding for piping subject to heavy service at high temperature.

On November 15th, the fifth of the educational series of lectures was presented by Mr. W. A. Miller, Asst. Chief Inspector, Chicago Division of the Hartford Steam Boiler Inspection and Insurance Company. Mr. Miller's subject was "The Inspection of Welding and the Qualification of Welding Operators." Mr. Miller's lecture clearly explained the function and service of the qualified inspection organizations to the art and industry of welding. About 60 members and guests were present.

PHILADELPHIA

Dr. H. J. Maxwell of E. I. du Pont de Nemours Co., spoke on the subject of "Welding Fabrication of Stainless Steel" at the November 20th meeting of the Philadelphia Section. Following his talk there was a lively discussion of the paper.

Mr. T. McLean Jasper of the A. O. Smith Corporation is to address the Section on the subject of "Modern Welding and Its Developments" at the January 15th meeting.

At the February 19th meeting Mr. I. T. Hook, Research Engineer of the American Brass Company, is scheduled to speak on "Welding of Copper Base Alloys." A representative of the Air Reduction Sales Co. will talk on "Flame Cleaning."

PITTSBURGH

Under the direction of the newly elected chairman, George F. Wolfe of the Dravo Corporation, the Pittsburgh Section opened the 1939–1940 Fall Season Wednesday night, October 18th, in the Auditorium of the Mellon Institute of Industrial Research, Oakland, Pittsburgh, Pa.

Speakers were V. W. Whitmer and H. L. Miller, both of the Metallurgical Department, Republic Steel Corporation, Massillon, Ohio.

Mr. Whitmer discussed the "Welding Problems in Stainless Steels in Transportation Equipment" while Mr. Miller covered the "Problems in Welding Low Alloy High Tensile Steels in Transportation Equipment."

Discussions covered general applications of stainless welding in various fields, but particularly in transportation and aircraft, and the methods used by various shops in the complete welding assembly of freight and passenger equipment. Both subjects were thoroughly covered by the speakers who used both slides and sound motion pictures to illustrate their discussions.

The audience of 86 members and guests was extremely interested and discussed various points brought out by the speakers for over an hour following the presentations.

The largest attendance of the year came out Wednesday, November 15th, to hear the speakers from Dravo Corporation discuss a modern welding shop layout and the manufacture of welded cranes and hoists.

Mr. George Wolfe, Chairman of the Pittsburgh Section, gave a most interesting paper on the modernization of their structural shop to suit the requirements for an efficient welding plant. This paper covered the changes made in relocation of equipment as well as continued a paper presented last year by Mr. Wolfe on the modern assembly plant for welding barges recently built by his company.

The second paper of the evening was presented by C. Perry Streithof, Structural Engineer for the same company, who discussed the welded fabrication of gantry cranes, welded hoists and other equipment used in connection with the hoists and cranes manufactured by his company. Mr. Streithof gave in detail the assembly and erection of the full revolving crane recently furnished and erected by his company in an eastern shipyard and showed in detail many interesting connections used in the assembly. Both papers were well illustrated with slides and were complete in all respects.

Vice-Chairman A. E. Marble presided at the meeting during the presentation of the papers by Mr. Wolfe. Following presentation of the papers an open discussion was held during which many of those in attendance asked numerous questions about the subjects covered by the two papers.

Announcement was made that following the usual custom of the Pittsburgh Section no meeting will be held during the month of December.

For the January meeting the Aluminum Company of America will furnish the speakers which will be announced at a later date.

PUGET SOUND

At the monthly dinner meeting held on October 23rd, Lieut. Commander W. R. Dowd, Construction Corps, U. S. N., spoke on "Erection and Welding of Naval Vessels to Control Distortion and Shrinkage."

At the regular Monday night dinner meeting held in November, 7 reels of sound pictures, "The Making and Shaping of Steel," sponsored by Columbia Steel Company, were shown. Mr. J. A. Luetke, Air Reduction Sales Co., discussed the subject, "New Applications of Cutting Apparatus."

ROCHESTER

The Rochester Section now numbering one hundred members on its second anniversary enjoyed for their December 7th meeting a discussion on "Welding in Power Equipment" by Mr. Norman L. Mochel of the South Philadelphia Plant of Westinghouse Electric and Manufacturing Co.

The program committee promises a meeting of equal interest for January with black and white movies of the "A B C's of Oxyacetylene Welding" and a colored film on "Welding of Red Brass Pipe." Mr. A. N. Kugler, Engineer with the Air Reduction Sales Co., is the speaker.

Mr. T. Gaylord of Eastman Kodak is to be presented with the Past-President's Pin at the January (anniversary) meeting.

The educational program of twenty lectures by Prof. Wm. Conley of the University of Rochester is being attended by about 40% of the SOCIETY members.

ST. LOUIS

At the regular meeting of the St. Louis Section held on December 8th, Mr. T. McLean Jasper, Technical Consultant to the Sales Department, A. O. Smith Corporation, outlined the various methods of welding from the early forge welding to the most modern methods of today. The most interesting development was the multi-layer shells for heavy pressure vessels.

Meeting dates, subjects and speakers for the first part of this year are as follows:

January 12, 1940—"A. W. S. Standard Qualification Procedure," by H. C. Boardman, Chicago Bridge & Iron Co., Chicago, Illinois.

February 9, 1940—"The Welding of Stainless Steel," by A. J. Moses, Combustion Engineering Co., Chattanooga, Tennessee.

March 14, 1940—(Joint Meeting with Engineers Club of St. Louis) "Welded Joints—When to Use and How Economically to Design Them," by L. C. Bibber, Carnegie-Illinois Steel Corp., Pittsburgh, Pennsylvania.

April 12, 1940—"Proper Designs for and Economies to be Effected by Welding," by A. E. Gibson, Wellman Engineering Co., Cleveland, Ohio.

May 10, 1940—"Welding of Nickel Alloys," by Frank Slocke, International Nickel Co., New York, N. Y.

June 8, 1940—Annual dinner meeting and entertainment.

SAN FRANCISCO

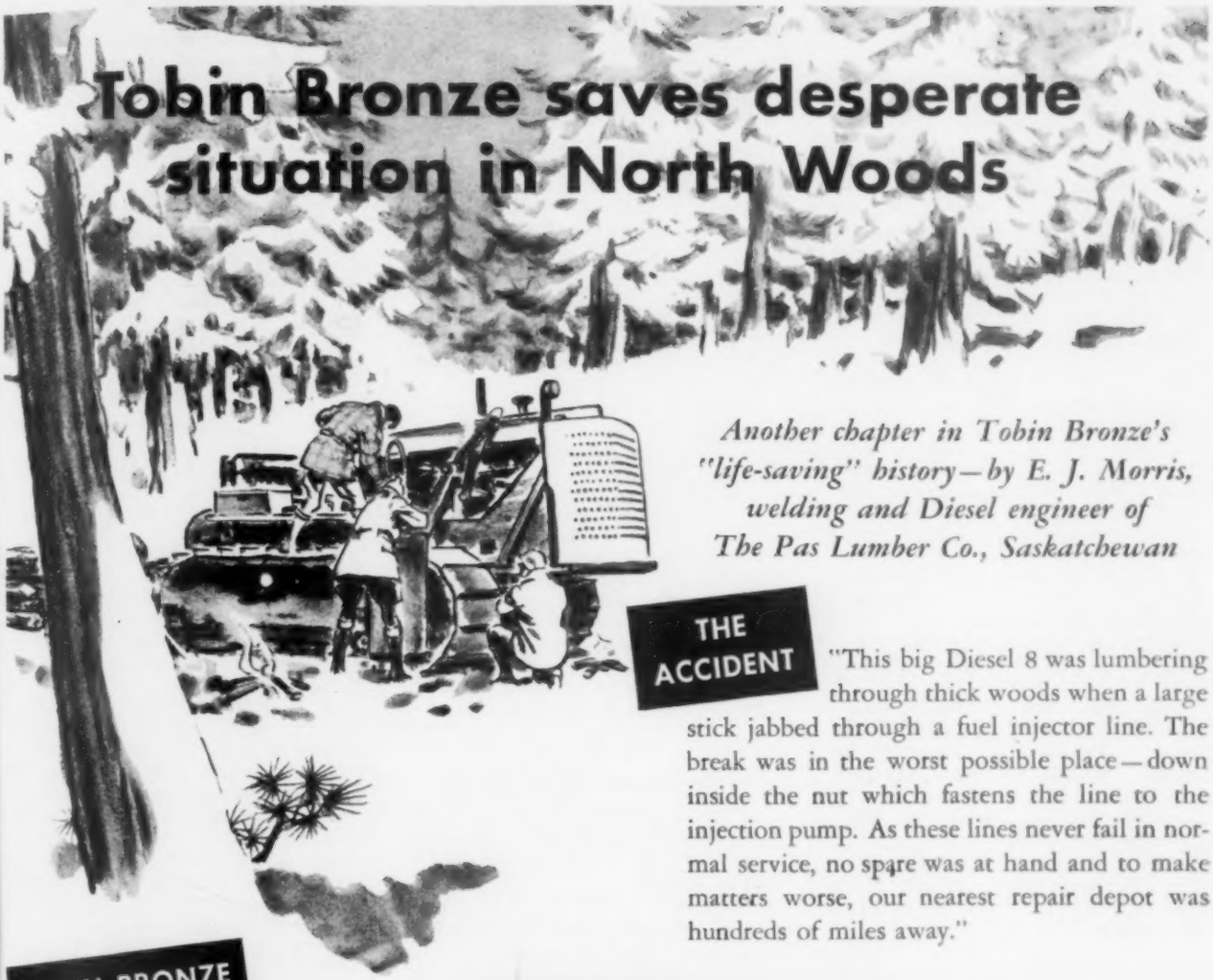
At the regular monthly meeting of the San Francisco Section held on November 3rd, an especially interesting program took place. Through the courtesy of the U. S. Steel Corporation a talking picture "The Making and Shaping of Steel" was shown, which was followed by a lively and interesting discussion.

Mr. James Close, Moore Dry Dock Company, Oakland, was the speaker at the December 8th meeting. His subject was on "Welding Problems in Ship Building."

SAN JOAQUIN VALLEY

At the October 27th meeting of the San Joaquin Valley Section, Mr. Russell L. Graves, Supervisor of Welding, Union Oil Company, discussed an interesting subject, "All-Welded Fabrication of Oil Storage Tanks." Mr. Graves discussed the welding design, procedure, technique and testing employed during the construction of several "All Welded Shell" tanks in accordance with A. P. I. Standards.

Tobin Bronze saves desperate situation in North Woods



Another chapter in Tobin Bronze's "life-saving" history—by E. J. Morris, welding and Diesel engineer of The Pas Lumber Co., Saskatchewan

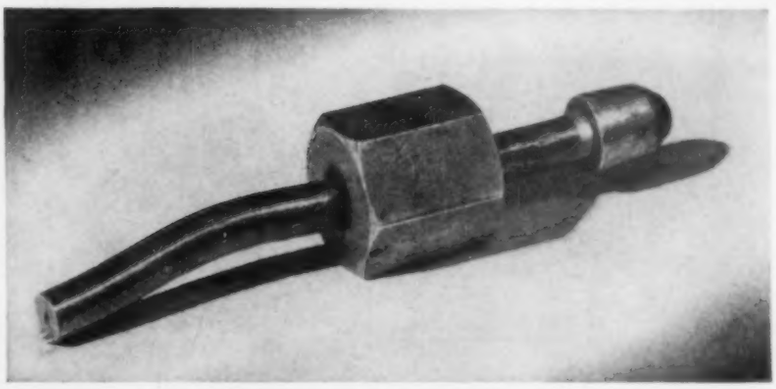
THE ACCIDENT

"This big Diesel 8 was lumbering through thick woods when a large stick jabbed through a fuel injector line. The break was in the worst possible place—down inside the nut which fastens the line to the injection pump. As these lines never fail in normal service, no spare was at hand and to make matters worse, our nearest repair depot was hundreds of miles away."

TOBIN BRONZE TO THE RESCUE

"We decided to try repairing the line with Tobin Bronze welding. In making the repair, the parts were ground cone shaped to allow almost complete penetration of bronze; alignment was secured by running a wire through the parts; and the weld made with Tobin Bronze. In about three hours, the machine was back at work and the welded line, which is subjected to pressures of 1800 to 2500 p.s.i., operated perfectly."

This is another instance proving the value of this Anaconda Welding Rod for difficult jobs on copper and copper alloys, steel and iron. Tobin Bronze carries the trade-mark "Tobin Bronze Reg. U. S. Pat. Off." in each rod. Look for this trade-mark and be sure you are getting the genuine. 39132



The new Anaconda 997 (Low Fuming) Welding Rod—high strength, tough weld metal with low fuming characteristics—is widely used for the general oxy-acetylene repair-welding of cast and malleable iron, steel and copper. Particularly valuable where repairs must be made quickly and easily on machinery parts, engine blocks, etc.

ANACONDA **Anaconda Welding Rods**

THE AMERICAN BRASS COMPANY, General Offices: Waterbury, Connecticut

In Canada: Anaconda American Brass Ltd., New Toronto, Ont. • Subsidiary of Anaconda Copper Mining Company

WASHINGTON, D. C.

The Washington Section is planning an educational lecture course consisting of eight or nine lectures to begin about the 1st of February. Details will be announced later.

At the meeting on November 20th, Mr. H. V. Thaden, Aircraft Engineer, Carnegie-Illinois Steel Corporation, delivered a very interesting lecture on the welding of stainless steel on aircraft construction. The attendance at this meeting which was a joint meeting with the Society of Automotive Engineers was between 150 and 200. Prior to the meeting, an informal speaker's dinner was given.

Programs for the next few months are as follows:

January 23, 1940. Meeting place: Potomac Electric Power Co.'s Auditorium. Subject: Developments in Welding in Shipbuilding. Speaker: H. W. Pierce, Welding Supervisor, New York Shipbuilding Corp.

February 27, 1940. Meeting place: Potomac Electric Power Co.'s Auditorium. Subject: Designers Problems in Welded Construction. Speaker: R. W. Clark, Welding Engineer, General Electric Company.

March 26, 1940. Meeting place: Potomac Electric Power Co.'s Auditorium. Subject: Influence of Weld Stresses. Speaker: Everett Chapman, President, Lukenweld, Inc.

April 23, 1940—Dinner Meeting. Meeting place: Harrington Hotel. Subject: Research Developments as Applied to Practical Applications. Speaker: Dr. Phillips Thomas, Research Engineer, Westinghouse Elec. & Mfg. Co.

YORK-CENTRAL PA.

The second meeting of the York-Central Pa. Section was held on November 27th. The following officers and new committees have been appointed for the coming year.

Chairman, J. W. Hennessey; Vice-Chairman, C. C. Keyser; Treasurer, A. T. Light; Secretary, C. B. Herrick.

Directors: (2 years) E. J. Brady, W. E. Hollingshead, E. E. Rouscher; (1 year) L. H. Kemper, T. J. Rainer, A. B. Heilman.

Program Committee: C. B. Herrick, Chairman, M. J. Van Dreser, E. J. Anderson, Oscar E. Weber.

Membership Committee: W. B. Lair, Chairman, Chas. W. Allen, H. W. King, J. A. Tapparo, T. J. Rainer, H. W. Motter.

The chief speaker of the evening was Mr. Leon C. Bibber, Welding Engineer of the Carnegie Illinois Steel Corp. who presented a very interesting talk on "The Experimental Background of Welded Design." This subject was very well illustrated by slides and after the presentation several questions were asked of Mr. Bibber all of which were taken care of very satisfactorily.

The attendance was well over 100.

CONTINUOUS WELDED RAIL

An illustrated folder just issued by Air Reduction Sales Company discusses Airco methods of preparing jointless track for mine car haulage.

The folder describes in detail three leading methods used in the butt welding of rail: bronze welding by the oxyacetylene process, steel welding by the oxyacetylene process, and steel welding by the metallic arc process. Complete descriptions cover preparation of the joint and equipment used, as well as common applications of the particular process.

An interesting commentary based on the results of exhaustive load tests is followed by a brief discussion of Airco equipment used in continuous rail welding. Copies of this folder may be obtained by writing Air Reduction Sales Company, 60 East 42nd Street, New York, N. Y.

FLAME GOUGING

Flame gouging, an oxyacetylene practice for grooving steel in preparing plate edges for welding, is described in a recently published booklet. The material is contained in an illustrated eight-page booklet, $8^1/_2$ x 11 in.

The flame-gouging process was developed originally for removing metal from the underside of welds and for removing defects revealed visually or by X-ray. It is now used for a variety of other operations, including the making of U-grooves in plate edge preparation. The booklet discusses various flame-gouging applications, and a description of the equipment and technique for applying the process. Photographs of actual applications and numerous sketches are included, as well as tables of operating data.

Copies of this booklet are available from the nearest office of The Linde Air Products Company.

Annual Banquet, A. W. S., Chicago, Oct. 26, 1939

$200,000 INDUSTRIAL PROGRESS AWARD PROGRAM IS ANNOUNCED BY THE LINCOLN FOUNDATION

458 Awards Offered for Studies Speeding the Benefits of Industrial Progress by Improving Designs, Manufacture, Fabrication, Construction and Maintenance of All Types of Machines, Building, Structures and Products

Cleveland, Ohio, Jan. 2, 1940.—A 2½-year program of scientific study, which will culminate in payment of $200,000 in awards, and which should produce widespread social and industrial benefits, was announced here today by The James F. Lincoln Arc Welding Foundation.

The 458 awards are established for studies bringing out benefits of a social, economic or commercial nature, such as reduction or elimination of hazards to safety and health, greater availability of comforts and conveniences through reduced prices, greater utility and durability of machines and structures as well as industrial benefits such as cost savings and other advantages in manufacture, fabrication or construction.

Studies encouraged with a view to creating such large-scale benefits will concern machines, products and structures of all types including: automobiles, trucks, buses, airplanes, locomotives, freight and passenger cars, street cars, ships and boats of all types, buildings, bridges, houses, furniture, heating and air-conditioning equipment, electric refrigerators, farming machinery, road-building equipment, as well as industrial machines and products of every conceivable kind.

Classifications and Divisions of Participation

Classifications	*Divisions*
A Automotive	*A*-1, Engines or Engine Accessories; *A*-2, Bodies or Body Accessories; *A*-3, Frames or Frame Accessories; *A*-4, Trailers
B Aircraft	*B*-1, Engines or Engine Accessories; *B*-2, Fuselages or Fuselage Accessories
C Railroad	*C*-1, Locomotives; *C*-2, Freight Cars; *C*-3, Passenger Cars; *C*-4, Locomotive and Car Parts
D Watercraft	*D*-1, Commercial; *D*-2, Pleasure
E Structural	*E*-1, Buildings and Similar Structures; *E*-2, Bridges; *E*-3, Houses; *E*-4, Miscellaneous
F Furniture and Fixtures	*F*-1, House; *F*-2, Office
G Commercial	*G*-1, Commercial Welders or Job Shops; *G*-2, Garages or Service Stations
H Containers	*H*-1, Contents Stationary (Tanks, etc.); *H*-2, Contents Moving (Pipe Lines, etc.)
I Welderies	*I*-1, Commercial Welderies; *I*-2, Plant Welderies
J Functional Machinery	*J*-1, Metal Cutting; *J*-2, Metal Forming; *J*-3, Electrical; *J*-4, Prime Movers; *J*-5, Conveying; *J*-6, Pumps and Compressors; *J*-7, Businesses; *J*-8, Functional Machinery not otherwise classified; *J*-9, Jigs and Fixtures; *J*-10, Parts of Functional Machinery.
K Industry Machinery	*K*-1, Processing; *K*-2, Construction; *K*-3, Petroleum; *K*-4, Steel Making; *K*-5, Farming; *K*-6, Household; *K*-7, Food Making; *K*-8, Textile and Clothing; *K*-9, Printing; *K*-10, Industry Machinery not otherwise classified.
L Maintenance	*L*-1, Machinery and Mechanical Equipment, including truck, bus and taxi fleets; *L*-2, Structures and other applications for arc welding in Maintenance such as pipe lines, railroad tracks, bridge strengthening, etc., not covered under *L*-1.

Awards

Awards, ranging from $13,700 to $100, and embracing the 12 classifications and 46 divisions into which the industrial field has been divided for purposes of participation (see accompanying table of Classifications and Divisions), consist of the following:

1st Grand Award—$13,700: The 1st Grand Award, which will be paid for the best progress report submitted, will total $13,700.

3 Main Program Awards: 1st, 2nd and 3rd awards of $10,000, $7500 and $5000.

48 Classificational Awards: 1st, 2nd, 3rd and 4th awards of $3000, $2000, $1000 and $800, respectively, in each of 12 classifications.

184 Divisional Awards: 1st, 2nd, 3rd and 4th awards of $700, $500, $250 and and $150, respectively, in each of 46 divisions.

223 Honorable Mention Awards: 223 awards of $100 each for papers which do not share in any other award but which deserve honorable mention.

Wide Range of Subjects

Innumerable subjects are suitable for study. The 12 classifications and 46 divisions of participation cover every conceivable machine, building, structure or product made of ferrous or non-ferrous metal.

Unlimited Opportunities for Participation

Participation in the Progress Program is open to everyone who plays any part in actually bringing about progress in the executive, design, fabrication, manufacture, construction or maintenance phase of industrial product or structure development. Authors of studies may be executives, engineers, designers, architects, draftsmen, plant superintendents, production managers, foremen, proprietors of automotive garages or service stations, owners and operators of fabricating and repair shops, or any other person engaged in the various phases previously mentioned. One author, or a group of authors, may submit a study. Any company or concern may submit more than one study, provided each is on a different subject and is prepared and submitted by a different author or group of authors.

Studies to Cite All Benefits of Progress

Studies may bring out any and all social, scientific, economic and commercial benefits which attest progress in industrial development. Studies must, however, report progress which can be attributed to application of the electric arc process of welding within the 2½-year period, January 1, 1940, to June 1, 1942. Such progress may involve one of the following: (*a*) Redesign and manufacture or construction of an existing machine, structure, building, manufactured or fabricated product of ferrous or non-ferrous metals; (*b*) New design and manufacture or construction of a machine, building, etc., as in (*a*); (*c*) Organization, development and conduct of a welding service; (*d*) Development, planning and performance of maintenance or repair work with arc welding.

Dedicated to general industrial progress, through scientific interest in and study of arc welding, this $200,000 Award to stimulate widespread study should be productive of far-reaching benefits.

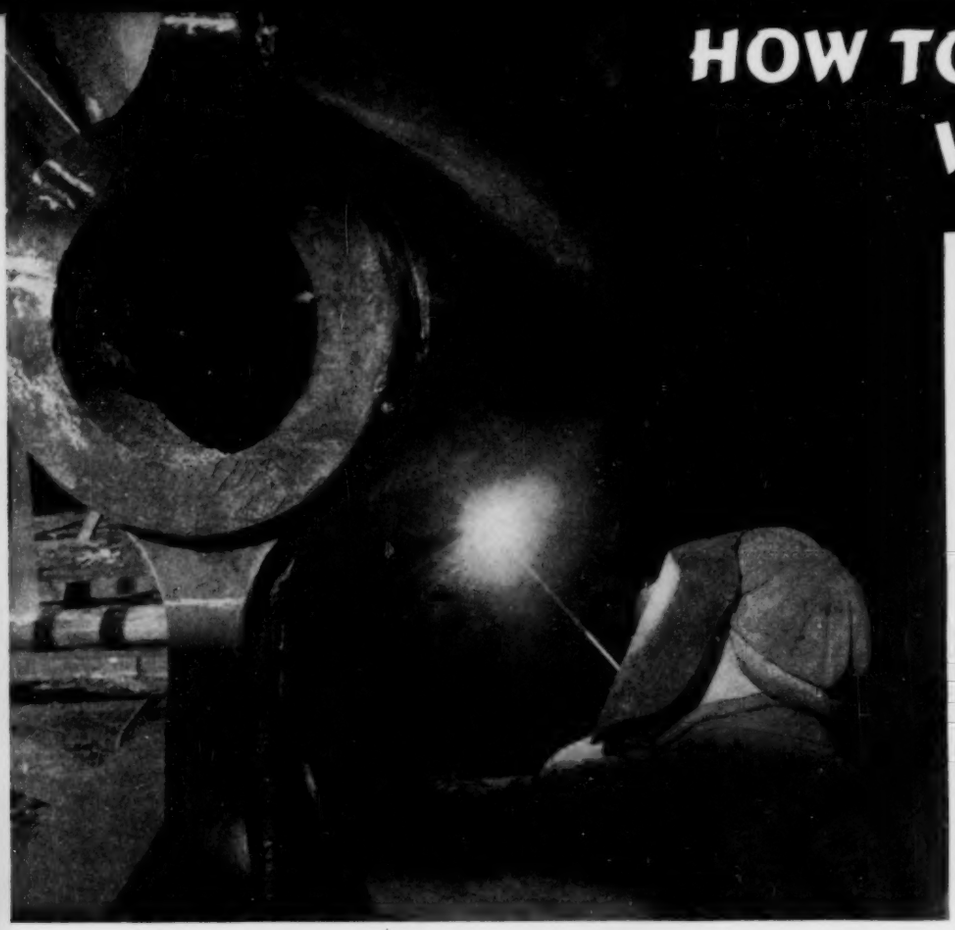
Participants in the Progress Program have 2½ years—from January 1, 1940, to June 1, 1942—to pursue their studies and prepare a report summarizing them. All those planning to qualify should record, for future reference, data in the form of designs, charts, photos, notes and other pertinent information on operations as of December 31, 1939.

All inquiries concerning the $200,000 Industrial Progress Award Program should be addressed: Secretary, The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

McKAY ELECTRODES WITH RYERSON

Joseph T. Ryerson & Son, Inc., of Chicago, have recently become distributors of McKay Certified Stainless Steel Electrodes. These highly specialized electrodes, covering the whole range of analyses encountered in stainless-steel welding, are stocked by all the Ryerson branches, including Milwaukee, St. Louis, Cincinnati, Detroit, Cleveland, Buffalo, Boston, Philadelphia and Jersey City, as well as the central plant in Chicago.

HOW TO REDUCE YO
WELDING COS



From coast to coast, in plants fab
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can effect real economies. Why n
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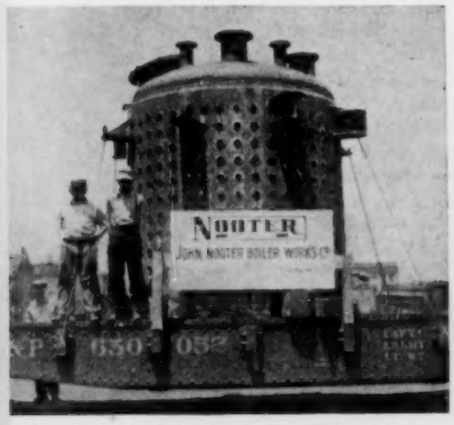
concerning welding procedure, h
experience may prove extremel

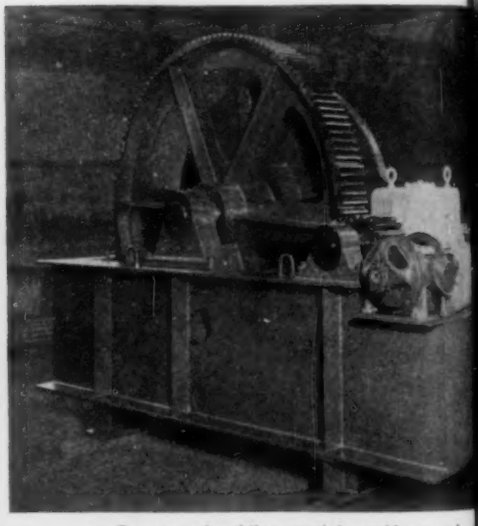
1 In marine work, vertical and overhead welding goes easily and quickly with Murex Vertex (reverse polarity) or Genex (straight polarity). *Photo courtesy Ira S. Bushey & Sons Co., Inc., Brooklyn, N. Y.*

We've a handy, pocket-size pamphlet giving appl
properties of each of the twenty electrodes in th
Send for your copy.

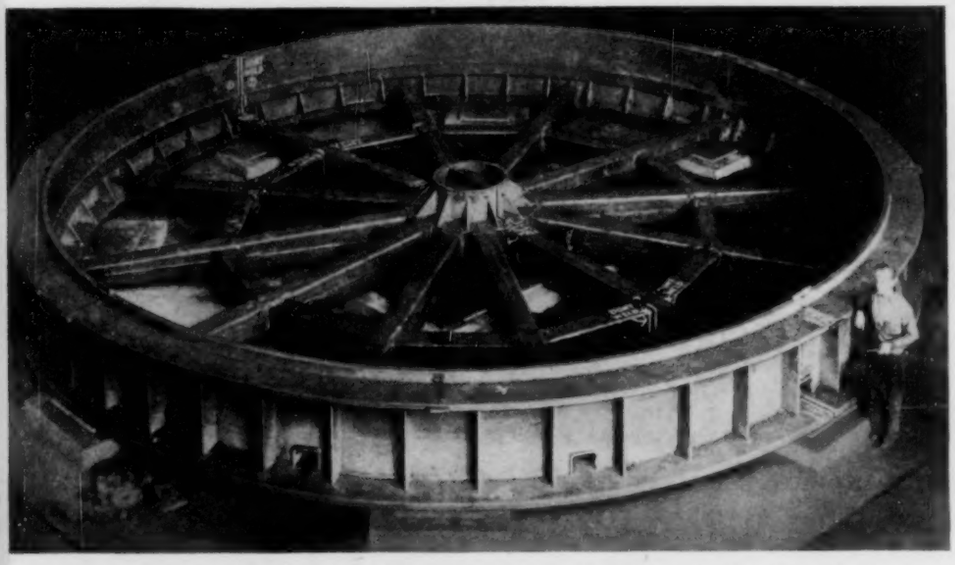


2 Only 2700 lbs. of Murex Type F were required for this all welded, staybolted, jacketed still, weighing 40,000 lbs. *Photo courtesy John Nooter Boiler Works Co., St. Louis, Mo.*

3 High speed deposition of consistently sound metal saves time and money in production of the new Lorain 79 Shovel with welded frame and boom. *Photo courtesy The Thew Shovel Company, Lorain, Ohio.*



5 Economy of welding special machinery such a gate hoist (one of four for a Govt. flood contro which even the gears are fabricated is promoted by time-saving Murex Electrodes. *Photo courtesy Lak & Steel Co., Milwaukee, Wis.*



4 Free-flowing Murex downhand electrodes speeded welding on this 96,200 lb. pot chuck, 33 ft. 7 in. in diameter. *Photo courtesy the fabricators, Lukenweld, Inc., Coatesville, Pa.*

MUREX
HEAVY COATED
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